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JUL 25 1930

INSTRUMENTS

INDUSTRIAL — SCIENTIFIC

(Reg. U. S. Pat. Off.)

Devoted to Measurement and Control Problems

Vol. 3. No. 7 Pittsburgh, Pa. July, 1930

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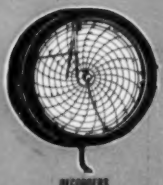
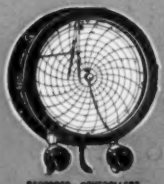
New Instruments

The AC-47 Radio Tube Tester
Type BME Battery Tester
New Well Type Manometer Checks Up Combustion Mixtures
Calculating Attachment For Textile Tensile Testing Machine
Single Strand Yarn Tester
The Determination of Gas Heat Value
Differential Limit Controller Applied to Metering Widely Varying Flow
A New Microscope For Shop Inspection Use
A Simple Method of Measuring the Specific Gravity of Liquids
Junior D.C. Multimeter
New S. & H. High Tension Fault Finder
A New Small-Motor Starting Switch
Combination Tester
A New Portable Immersion Pyrometer
New Coil Testing Instrument

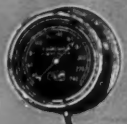
Place initials of interested persons in your organization opposite title and call it to their attention.



RECORDERS

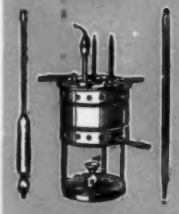


RECORDER - CONTROLLERS

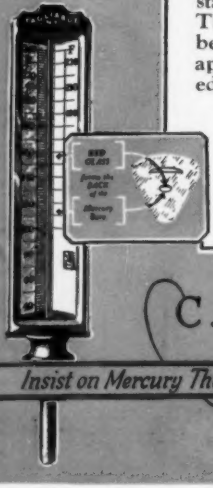


DIAL - INDICATING THERMOMETERS

AUTOMATIC CONTROLLERS



OIL TESTING INSTRUMENTS, VISCOMETERS, HYDROMETERS, ETC



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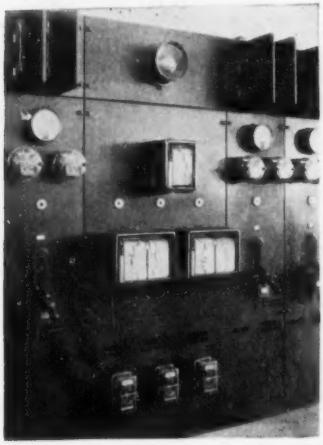
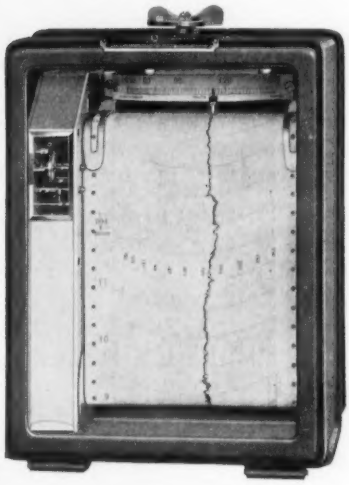


Switchboard installation of Esterline-Angus Wattmeter, Ammeter, Voltmeter, Power-Factor meter and Frequency meter (two twin-type and one single) in large printing plant.



EVERYTHING THEY WANT TO KNOW » »

From ONE Switchboard Installation of ESTERLINE-ANGUS METERS

As an example of the growing appreciation for the information revealed by graphic recording instruments in industrial plants, the illustration at the top of this page is of interest to engineers and executives everywhere.

Here, in a large printing establishment, by means of an ingenious switchboard mounting of five types of Esterline-Angus graphic recording instruments, any one of these meters may be connected at will in the circuits of departments or individual machines. Thus by the simple process of throwing a switch, the management is enabled to observe the condition and functioning of motors and equipment; to record power consumption; check power charges; watch productive effort; make accurate time-studies, etc., etc. Meters operate continuously over a period of a full week, if desired, without attention.

May we send further facts? Esterline-Angus instruments are used in scores of industries for obtaining vital operating data. Perhaps some of these uses will offer valuable suggestions to you.

THE ESTERLINE-ANGUS COMPANY
INDIANAPOLIS, U.S.A.

Pioneers in the Manufacture of Graphic Recording Instruments

When writing to the above company, please mention INSTRUMENTS

"the same as Foxboro"

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"Our V-Port Valve is the same as Foxboro."

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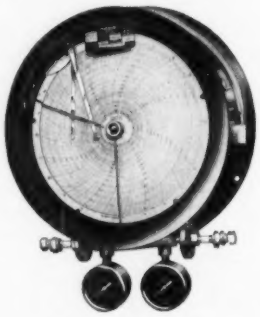
We like to hear that.

It proves that Foxboro sets the Standard for Appearance, Accuracy, Convenience and Performance.

But Foxboro can never be successfully imitated.

From coast to coast, industry is finding that out. Wherever control is a matter of vital importance Foxboro Controllers become a necessity. Because they are sensitive, accurate, dependable; and are based upon sound engineering.

If you want satisfactory temperature control, write to us, Dept. A. E. We can help you.



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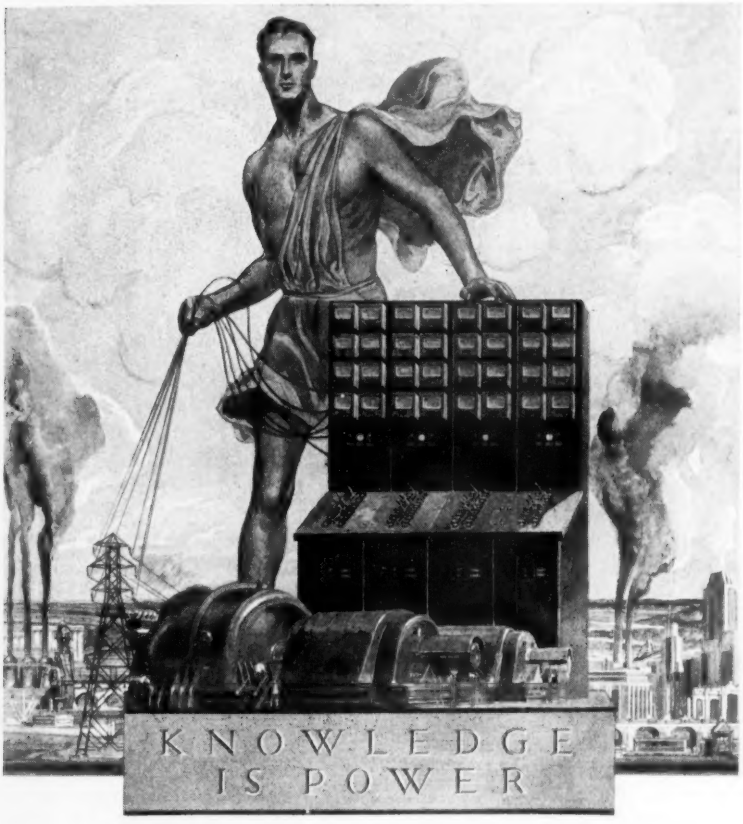

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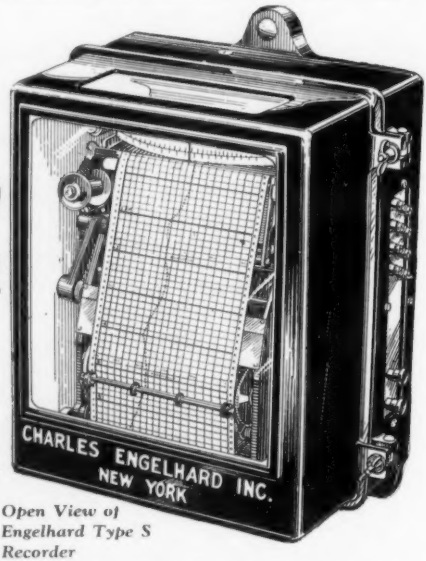

Open View of Engelhard Type S Recorder

Industry today demands dependability and longer life of equipment. Thirty years of expert engineering knowledge is back of the designing and construction of the Engelhard Recorder . . . and with one objective only . . . to make only the best Pyrometer to withstand the most severe service.

The driving power which is furnished by the solenoid, operating from lighting circuit, is several times greater than necessary. A powerful jeweled six or eight day clock times the chart and makes intermittent electrical contact where D.C. is available. An electric clock is furnished for A.C. operation.

The thoroughly dead beat moving coil has double filament support, without pivots or hair springs. It is extremely rugged and super accurate.

Automatic switches are furnished on multi-point instruments each consisting of a small glass bulb containing mercury, sealed in platinum electrodes and are successively tilted by the operating solenoid. They eliminate contact corrosion.

The Engelhard Recorder is furnished with adjustable platinum iridium maximum and minimum contacts. May be had calibrated for use with thermo-couples, electric resistance thermometers, thermal conductivity type of gas analyzers, microammeters, millivoltmeters, voltmeters, ammeters and as pyheliometers.

Every Engelhard Type S Recorder —like all Engelhard Instruments, is precisely made of the finest obtainable materials—designed for long service under severe conditions and carefully tested for accuracy.

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Recording and indicating instruments, automatic temperature and gas control, pyrometers, gas analyzers, thermocouples, thermometers.

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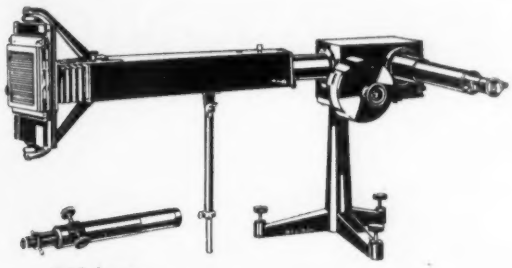

B & L Large Spectrometer with all-metal Camera

Spectrum Analysis » for Precision Control

THE exact analysis afforded by spectrum examinations makes the Spectrometer and the Spectrographic Camera of utmost value in the laboratories of most manufacturers.

The large B & L Spectrometer, with all working parts completely enclosed for protection against dust and corrosion, is an instrument for the most delicate work. An all-metal Camera provides for spectrum photography. Its construction reduces the possibility of warping to a minimum and insures permanency of adjustments.

The smaller B & L model, the Laboratory Wavelength Spectrometer, is unsurpassed for routine laboratory work. An all-metal Camera is also available for this model.

Write for complete information.

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MULTIMETER JUNIOR
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5″ x 4⅜″ x 2⅛″
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Twelve Ranges—1 microampere to 1 ampere (1,000,000 mics)
20 microvolts to 1000 volts

Just 3 Binding Posts and 1 Selector Switch

Specially suitable for covering both minimum and maximum readings on separate mounted thermo couples in vacuo
For High Frequency Work

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Write for bulletins.

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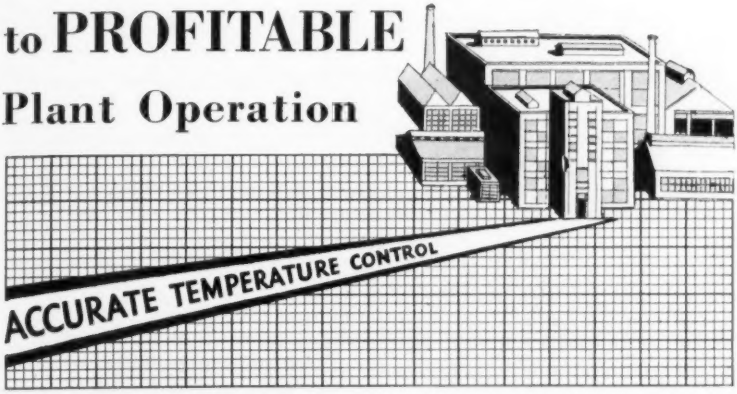
Treading the Narrow Way to PROFITABLE Plant Operation

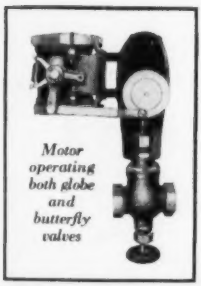


Precision control of temperature, in practically any industrial process, can be readily obtained by installing Minneapolis-Honeywell temperature regulating units.

Temperature controller

These units operate Minneapolis-Honeywell solenoid or motor actuated valves—controlling the flow of liquids, steam, gas, oil, air, etc. Valves are either controlled directly, or through Minneapolis-Honeywell relays, or operate in conjunction with pyrometers of any standard make.

The instruments here illustrated are typical of the broad Minneapolis-Honeywell line of temperature, pressure and combustion controls. Industrial Catalog and engineering service available to you without obligation of any kind. Just clip and mail the coupon.


Motor operating both globe and butterfly valves

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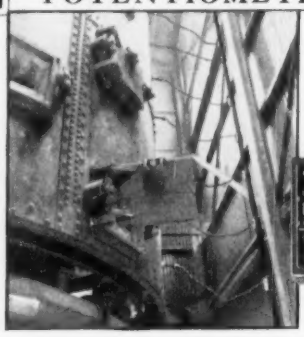
Leads Corrode

But Accuracy Remains

With POTENTIOMETER PYROMETERS



Actual width of the L & N chart is 9⅞ inches

ELECTRICAL resistance changes anywhere along the leads do not affect the accuracy of L & N Potentiometer Pyrometers. Wires may corrode or contacts vary at terminals and switches—yet if there is contact, readings stay within a deadline of 3° in 1000°.

And this is but one of the ways in which the L & N Potentiometer* Pyrometer is trouble-proof. This null potentiometer method of measuring temperatures—balancing the unknown thermocouple millivoltage against a known millivoltage from the instrument—is at once the most accurate and reliable in industry.

Back of L & N Potentiometer Pyrometers is the knowledge and experience gained from thousands of installations in thousands of plants.

L & N Catalog 84-I lists L & N Potentiometer Pyrometers for automatic temperature control. Catalog 87-I lists them for recording and for indicating. Special bulletins outline their application to various industries.

**Information as to the advantages of L & N Potentiometers will be sent on request.*

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LEEDS & NORTHRUP

P-207 Cleveland Chicago Houston Los Angeles San Francisco

Different Pyrometers—The Most Accurate Pyrometers In Industry

For Indicating, for Recording and for Controlling Automatically

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Published the 15th of each month by

INSTRUMENTS PUBLISHING COMPANY

1117 WOLFENDALE STREET, PITTSBURGH, PA.

JOSEPH J. VIGNEAU, *President* RICHARD RIMBACH, *Vice-Pres. & Treasurer*

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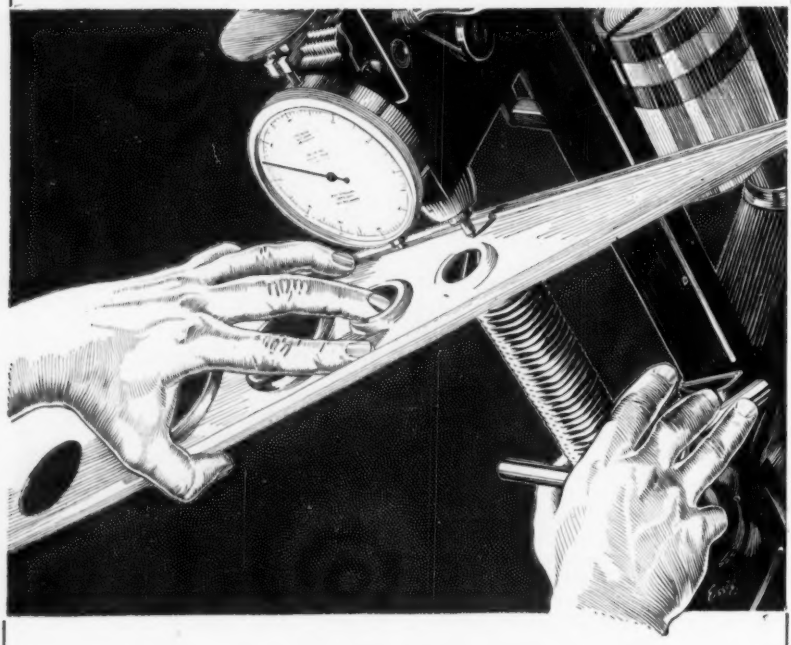
The Douglas Aircraft Co., Inc.
make extensive use of the

ROCKWELL HARDNESS TESTER



They exert every effort to see that each plane is well and carefully built and have given us permission to publish this drawing showing one of the Rockwell Testing operations in their inspection department.

WILSON-MAEULEN CO
INCORPORATED

387 Concord Ave. New York, N. Y.

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INSTRUMENTS
INDUSTRIAL — SCIENTIFIC

(Reg. U. S. Pat. Off.)

Vol. 3, No. 7 JULY, 1930 Pittsburgh, Pa.

To Our Readers

A NUMBER of letters were received by the editor as a result of the articles, for and against the Metric System, appearing in our columns. We quote a part of one here:

> It seems very important that a clear picture be had of the trend of sentiment in regard to the adoption of the metric system to replace other measuring systems in the United States. Any measuring system would affect the entire population of the country, but it is apparent that a small group of thinking people must decide what system ought to be given the preference for exclusive use. I think it fitting that INSTRUMENTS should conduct an investigation and that articles pro and con on the various measuring systems are to appear in your publication.
>
> There is no doubt that a thorough study of the question must precede the passage of any legislation although legislation on a measuring system cannot be classed with such legislation as the Volstead Act, for instance. The latter is a direct infringement on the personal rights of individuals, whereas it is a foregone conclusion that there must be certain standard measuring tables in use to facilitate trade. There is merely the question as to which system shall be the standard.

Beginning the end of this month, INSTRUMENTS will start mailing out ballots to determine the sentiment in reference to the Metric System among engineers and scientists, who represent the *small group of thinking people*, mentioned in the above quoted letter.

In preparation for this poll on measuring and weighing systems two articles appeared in our publication presenting the two sides of the question. One of these articles appeared in the May issue, the other in June.

To be sure any change to another system will cost money; but if it appears that a change in our system of weights and measures is desirable, it would be best and most economically accomplished at the earliest possible moment.

In any poll the losing side is always ready to explain that the poll was not fair, that the organization sponsoring the poll was biased, that all the individuals who received ballots but did not vote should be added to their total, etc., etc.

It is the earnest wish of the editor to avoid the alibi stories. We therefore urge everyone receiving a ballot to vote. Make this poll effective, by filling out and returning your ballot immediately after you receive it. This will permit our work in tabulating the results to be accomplished more quickly and with a high degree of efficiency.

Elmer A. Sperry

(1860-1930)

ELMER A. SPERRY, born in Cortland, N. Y., Oct. 12, 1860, received his early training at the State Normal and Training School at Cortland, later attending Cornell University. He was the son of Stephen Decatur and Mary (Borst) Sperry, a direct descendant of Richard Sperry, who, in 1660, at the New Haven Colony secreted and maintained in Judges Cave three of the judges who condemned Charles I.

With his inventive quality Sperry combined business acumen and judgment. He was one of the small number of inventors who himself was able to reap a financial reward worthy of his achievements.

In 1880, at the age of twenty, he founded the Sperry Electric Company in Chicago. This company manufactured arc lamps, dynamos, etc. Some time later he organized the Sperry Electric Railway Company in Cleveland. The latter company was sold to the General Electric Company in 1894.

In 1910 he organized and was president of the Sperry Gyroscope Company in New York. The gyroscope was brought before the public by him and he became the leading authority on gyroscopic action. He perfected the gyro-compass and applied it to both ships and airplanes. Much of the modern development in the air is credited to his airplane stabilizer. Other developments made under his direction were: automatic stearing, high intensity searchlights, fire control apparatus, airplane and navigational equipment, etc.

In January 1929, he sold the Sperry Gyroscope Company to the North American Aviation Company and immediately thereafter started building up the Sperry Development Co., Inc., which he had organized in 1926, and also the Sperry Rail Service Corporation. The two companies manufacture gyro track inspection cars, transverse fissure detection apparatus and various types of steel testing equipment. In 1930 he combined these two companies and became Chairman of the Board of the Sperry Products, Inc.

He was the author of many papers and addresses before engineering and technical societies. Sperry was able to make science fascinating to others. Twenty years ago he appeared as a lecturer in many places in this country and illustrated the wonders of the gyroscope, the freaks of electricity, the marvels of liquid air and other phenomena.

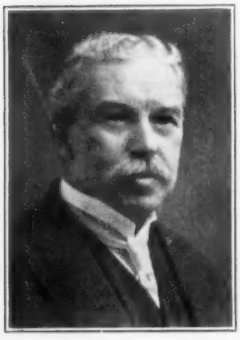
Academical honors were showered on Sperry; he was a D. E., Stevens Institute of Technology, Sc. D., Northwestern University and a D. E., Lehigh University. He was awarded the First Prize, Aero Club of France in 1914 for the airplane stabilizer; two Franklin Institute metals, 1914 and

1929; Collier Trophies, 1915 and 1916; Holley Medal, 1927; John Fritz medal, 1927; Albert Gary medal of the American Iron & Steel Institute, 1929; two decorations from the late Czar of Russia; two decorations from the Emperor of Japan; Grand Prize, Panama Exposition.

Sperry was a member of the U. S. Naval Consulting Board; a member of the Council of the American Society of Naval Architects & Marine Engineers; President of the American Society of Mechanical Engineers; founder member of the American Electrochemical Society; charter member of the American Institute of Electrical Engineers; Chairman, Division of Engineering & Industrial Research, National Research Council; honorary member, Japanese Society of Mechanical Engineers; a member of the Society of Automotive Engineers, National Academy of Sciences, Japanese Society of Naval Architects, Japanese Society of Electrical Engineers, Japanese Society of Illuminating Engineers, and Engineering Association of Hawaii. He was Chairman of the American Committee of the recent World Engineering Congress at Tokyo.

In Chicago, Ill., on June 28, 1887, Sperry married Zula A. Goodman. Childred are Edward G., Helen M., Lawrence B. (deceased), and Elmer A. Jr.

His death on June 16, 1930 closed a career in which over 400 patents were granted in widely separate fields: mining machinery, electro-chemical processes, machinery for making fuse wires, an electric automobile, instruments, etc.



William Henry Bristol
(1859-1930)

WILLIAM HENRY BRISTOL, inventor, educator, manufacturer, founder of The Bristol Company of Waterbury, Connecticut, and one of its most substantial and progressive citizens, was born in Waterbury, July 5, 1859. He was a son of the late Benjamin H. Bristol and Pauline Phelps Bristol, both of whom were of English ancestry.

William Henry Bristol studied in the public schools in Naugatuck until 1876, when he became a clerk in a general store in that town, working there until 1880. He had, from early youth, evinced decided mechanical genius, and had a scientific mind which he was ambitious to develop into something that would ultimately be of benefit to mankind. With this object continually before him, he studied and determined to attend some school of higher scientific training. As soon as his savings were sufficient to avail himself of the scientific course at Stevens Institute of Technology, he entered that institution at Hoboken, New Jersey, working his way through by his own earnings and completing his course there.

During his junior year, Bristol organized the manual-instruction department in the Workingman's School in New York City, and taught there while continuing his courses at the Stevens Institute. In 1884 he was graduated with degree of M.E., after which he kept up his classes at the Workingman's School for two years. This school was founded by, and sponsored by Professor Felix Adler, who was one of the pioneers in manual training and the arts, and the first to promote that work in New York.

In 1886 he was appointed instructor in mathematics at Stevens Institute, and two years later assistant professor in that department. In 1899 he was given the title of Professor of Mathematics.

While pursuing his studies at Stevens, Bristol gave considerable time and attention to inventing, perfecting and manufacturing a series of recording instruments adapted to making continuous records of pressure, temperature and electricity. He was a pioneer in the manufacture of recording instruments in America. During the many years he has devoted to this work, he has developed a complete line of recording instruments adapted to meet almost every industrial requirement, covering the most complete variety of ranges for the measurement of pressure, temperature, electricity, speed, time, etc. His recording pressure gages, recording voltmeters, wattmeters, ampere meters, recording thermometers, pyrometers and patent steel belt lacing are in universal use.

In 1899 Prof. Bristol founded The Bristol Company at Platt's Bridge, Waterbury, for the purpose of manufacturing and marketing his inventions. He had been the dominant figure in the progress and development of the company and its executive head to the present time, covering a period of 40 years.

At the Chicago Exposition in 1893, Prof. Bristol was awarded a medal and a diploma for an exhibit of recording instruments. He was awarded the Edward Longstreet medal in 1894 at Philadelphia. At the Paris Exposition in 1900, he was awarded a silver medal. At the St. Louis Exposition in 1904 his recorders were awarded a gold medal. He received many other medals from various expositions all over the world, also recognition of the excellence of his inventions including the John Scott Legacy Medal which was awarded him by the Franklin Institute at Philadelphia in 1890. He was also awarded a medal at the Sesqui-Centennial at Philadelphia in 1926.

Prof. Bristol also invented a system of thermoelectric pyrometers for the measurement of high temperature, and numerous other instruments for automatically recording extremely delicate movements of an indicating arm where the least friction would cause inaccuracy in a record.

Prof. Bristol was a pioneer in the field of sound recording devices and had devoted the major part of his time for several years to bringing it to the state of perfection now attained. In 1915 he conceived the idea of recording simultaneously what is seen and heard, in permanent form, so that such records may be reproduced at any future time or place as if the characters were really present talking and acting. The method he chose to accomplish this was to record simultaneously the sound on a phonograph disc, at the same time that the motion pictures of the persons and scenes of action were photographically recorded on a "movie" film. By reproducing the sound record and the film simultaneously, and synchronously, the sounds and actions are heard and re-enacted as in the original. This method combined the two arts of phonograph recording and motion picture photography

without involving any radically different methods of recording the sound or necessitating any change in the picture film itself. This method is far in advance of any other thus far advanced, and has decided advantages over any other process in the production of both the sound and the photographic record. The design and development of the apparatus necessary for making and reproducing talking motion pictures of this type, covers several fields of engineering science, and no man in the engineering world is more fully equipped in experience, invention, genius and knowledge of this subject than was Prof. Bristol, who had devoted so many years of his busy life to the practical development of sound recording devices.

The individual character developed in the Bristolphone is unique, inasmuch as it combines all the elements of successful production necessary, and the numerous patents, basic and otherwise, as combined in the Bristolphone are sound and all covered and recognized. The Bristolphone is in successful operation in hundreds of the best moving picture houses at the present time. One feature of the Bristolphone which no other invention has, is the certainty of precision in synchronization, which is regulated by a device for that purpose, that will at once rectify, by retarding or advancing the sound record, any error in the production of the sound or lip movement of the actors.

He was ill for several months with a blood clot near the heart and died June 18, 1930.

Prof. Bristol was a member of the American Society of Mechanical Engineers, Fellow of the American Association for the Advancement of Science, American Institute of Electrical Engineers, Society of Electro-Chemical Engineers, Society of Motion Picture Engineers, and numerous others.

He was first married to Miss J. Louise Wright in 1885 and she died three years later. June 28, 1899, he was married to Elise H. Myers, who was a granddaughter of General Michael Myers. She passed away August 5, 1924.

ANNOUNCEMENT is made by Cutler-Hammer, Inc., Milwaukee, Wis., that effective May 1st it has purchased the assets of Union Electric Manufacturing Co., also of Milwaukee, manufacturers of Motor Control specializing in a very complete line of drum type control apparatus.

The addition of the Union line to that of the Cutler-Hammer line enables Cutler-Hammer to supply any requirement of its customers in drum type motor control apparatus.

The branch sales offices and warehouse stocks of Union will be consolidated immediately with the Cutler-Hammer branch offices and warehouses The present factory of Union will be operated as a manufacturing division of Cutler-Hammer. Mr. E. F. Le Noir, President of Union, will become a member of the headquarters sales staff of Cutler-Hammer. Most of the Union personnel, particularly those in the Sales and Engineering Departments, will also join the C-H organization.

The Matheson Co., of North Bergen, is removing to new quarters in East Rutherford, N. J., and will be established there after July first.

INSTRUMENTS BOOK SHELF

The books reviewed in this section can be supplied by Instruments Book Shelf, Instruments Publishing Company, Pittsburgh, Pa.

Scientific Management in American Industry. *The Taylor Society.* Harper & Bros., New York, 1929. Cloth, 6x9¼ inches, 500 pages, 90 figs. Price $6.00.

"The Taylor Society" is the composite author of this ambitious review of a decade's progress in the application of that group of premises, principles and procedures known as scientific management. Twenty-six individual contributors, under the leadership of Morris Llewellyn Cooke (then president of the Taylor Society and himself one of the contributors) and under the "scientific management" of Dr. H. S. Person, Managing Director, collaborated in summarizing the wealth of data on this subject, in defining its status and in estimating its influence. This work not only tells what scientific management is, but what it has done and can do. Throughout its 6 Parts and 29 Chapters, there is not one over-enthusiastic statement. The exposition is lucid and therefore convincing. To engineering executives this book should primarily appeal as a résumé of the scientific management movement—which would appear to be its main scope—and beyond that it should serve to summarize a great deal of scattered recent data on the subject. This book by no means supplants "Management's Handbook" and other reference sources. It however presents management problems in what for want of a more exact term we may designate a "literary" manner. On the whole, this long book is pleasantly and fruitfully readable. As to its completeness, the reviewer can only judge from one viewpoint: that of the application of industrial instruments. The words 'Instruments," "Gages," "Measurement" do not appear in the index and the only mention of instruments in the entire book is the following paragraph, which appears in Part V (Control), 2. (The Maintenance of Standards), Chapter XXIII, (Inspection of Physical Standards), heading, "Materials and Products," sub-heading, "3, Materials in Process."

> "In some plants special physical laboratories have been constructed, with a complete equipment of the most precise and delicate measuring apparatus, for the purpose of inspection and maintenance of working gauges, tools and similar equipment."

From the reviewer's "instrument-conscious" viewpoint, this is a deplorable oversight. And perhaps the reviewer will be joined in this opinion by engineering readers of "Scientific Management in American Industry." Certain it is that among the thousands of engineers who yearly pay the price of the subscription to INSTRUMENTS a large percentage occupy managerial positions. Or, to put it in another way, certain it is that of the engineers who occupy managerial positions in American industry a goodly percentage are avid readers of INSTRUMENTS and of various industrial and engineering periodicals in which the developments and applications of industrial instruments are written up. This is not offered as a carping criticism of a minor shortcoming: It is believed that in the assignment of subjects to the 26 famous contributors, a serious oversight occurred. It is hoped that this gap will be filled in subsequent editions.

Of particular interest to the class of readers typified by subscribers to INSTRUMENTS are Parts IV and V, comprising nine chapters, devoted to the control of operations and to the maintenance of standards. It was these 2 parts of the book which the reviewer read with especial care in the vain hope of finding adequate reference to the important role of industrial instruments in the introduction and application of scientific management.

Apart from this oversight, the eminence of the 26 contributors constitutes an assurance that this book fills the need for a comprehensive and up-to-date treatise on scientific management.—M. F. Béhar.

Le Controle de la Dureté des Métaux dans L'Industrie. *P. Roudie.* Dunod, Paris, 1930. Paper, 6½x10 inches, 114 pages, 6 figs. Price 26 Fr.

One is seldom priviledged to see a book in which a question of the greatest industrial importance has the light of creative criticism focused on it in a more graceful and thorough manner than in the present booklet.

It belongs to the type of work, which does not introduce any radical changes in the conception of the subject, but presents already available data in the light of a thoroughly trained analytical mind, so that the details stand out sufficiently to attract attention, inevitably leading to further creative approach.

A clear understanding of a problem is the best approach to its solution. The presentation of the conception of hardness and of the methods for its determination, can hardly be improved, either in thoroughness or clearness. A brief picture of the chaos hiding under contemporary looseness of the definition of hardness and the secondary phenomena entering into all known means for its determination, is followed by an outline of 6 kinds of hardness generally accepted in the literature. Crisp reviews of testing methods, both obscure and well known, pass in review, and serve as an introduction to the scholarly discussion of the relation between elasticity and hardness. On the foundation built in the preceding chapters tne performance of the scleroscope is critically considered on 53 pages, explaining many peculiarities of the performance of this instrument—the most promising from the theoretical point of view.

The author's knowledge of the subject is exhaustive, ranging from the highly theoretical work of Weyl, Cauchy Kelvin and others, to the wholly practical of industrial testing routine. M. Roudie is so sure of his ground, that he discards the annoying habit of many French writers, of attaching themselves to the apron strings of some well known man via an introduction to their work.

In the preface the author mentioned that the volume under discussion is to be considered as a mere introd ction to the forthcoming treatise on the subject. What this will be, one can only speculate, because the reviewer cannot recollect a clearer, more comprehensive and better description and interpretation of hardness and the phenomena accompanying the methods of its determination than is given in this mere introduction—the present little volume. —John D. Gat.

Measurements

Industrial & Scientific

An Instruction Book for Engineers

DR. WALTER BLOCK

Eichungsdirektor der Provinz Ostpreussen

CHAPTER VI. MEASUREMENTS OF LENGTH

1. General Remarks and Standards

With the exception of weighing, measurements of lengths are of greatest importance for the physicist and chemist; they shall, therefore, be treated somewhat more exhaustively according to their general importance. Lengths can be represented by the distance between two points or two lines, or as it occurs much more often in practice, by the distance between two surfaces. If, on a piece of material to be machined two punch points are made or two places marked by lines we have the first case, the length of a railroad rail, on the other hand, is characterized by the distance of its two end faces. In the same way, the diameter of a sphere is determined by the distance of two planes which, in this particular case are represented by a single one, the plane passing through a diameter. If now a length is to be measured it will, in general, be more advisable to start from this difference in the representation of the length. Therefore, technically two kinds of measures of lengths are distinguished, namely end measures and line-measures. The latter are more generally known in daily life and are represented by the usual rules. The distance between two divisions therefore indicates a certain length. They have the further advantage that one rule can represent many individual lengths.

On the other hand, the pure end measures have the disadvantage that they can represent, in general, only one definite length. For example, if a cylindrical steel body is machined so that its two end faces are exactly parallel to each other at a distance of 100 mm, such a measuring body represents an end measure for the length of 100 mm and can be used as will readily be seen to determine the distance between two surfaces with very great accuracy. Such end measures are used in numerous kinds in industrial plants. A combination end and line-measure is the familiar caliper. It has, as is known, a division in lines and a rigid leg at one end while a second movable measuring leg is movable on the division itself. Both are adjusted in such manner that they coincide with their measuring faces when an index on the movable leg coincides with the zero point of the division. If one separates the two legs, the distance between the two measuring faces is exactly equal to the reading of the division. The end measure is here represented by the distance of the two faces, namely the faces of the two measuring legs, and one has, in this case, a variable end measure which can be adjusted for any desired distance.

For the laboratory, especially for chemical purposes, line measures are principally used for the measurement of length. These are manufactured industrially in a great many different kinds, shapes, accuracy of division, and lengths so that it is not difficult to find suitable measures for any purpose. Quite generally it may be pointed out that at present it is not yet possible to manufacture longer measures so that all lines are absolutely accurate. Even in the best measures one will always have to figure with an accuracy of each line of a few thousandths of a millimeter. Longer measures which need only be accurate to a few hundredths of a millimeter can be obtained easily. It is different with small scales up to about 100 mm length. They can be obtained from the best manufacturers where the error of the line divisions seldom exceeds more than 1/1000 mm.

It must, however, be considered that the length of all measures are influenced to a comparatively large degree by temperature as soon as one works with long lengths and desires somewhat greater accuracy. It must be taken into account that the usual materials for measures have a temperature expansion coefficient between 1 and 2 hundred thousandths, i. e., each measuring length changes its length at an increase of 1° in temperature by 1 to 2 hundred thousandths. In particular it must be remembered that the two principal materials for measures, steel and brass have expansion coefficients on an average of 11.5 and 19 x 10^{-6} respectively, which means that a brass measuring rod which at 0° has the exact length of 1 m is, at 20°C longer by 0.38 mm than 1 m, while a similar measuring rod of steel is longer by 0.23 mm, therefore shows a fairly noticeable difference compared to the brass rod. For all exact length measurements, this temperature error will have to be taken into account. In some respects, however, the matter is somewhat simpler. If measurements need be made only at the usual laboratory temperature the continual reduction to 0° need not be made; at present all measuring tools are adjusted to the standard temperature of 20°C[1]) so that by working at or near this temperature no errors are made. Further, another point must be considered. If, for instance, two points are marked at 0° on an iron plate by means of a correct scale, which is also of iron or steel, exactly 1 m apart, and if this scale and iron piece are exposed to different temperatures and care is taken that both temperatures are the same, it is at once obvious that under this condition the distance of the two marks measured with the scale must again give the same result, because as piece and scale are of the same material they expand equally with temperature changes, therefore their lengths change uniformly, which means errors of temperatures are excluded, of course under the supposition that the expansion coefficients of both pieces are actually the same. In conclusion it can therefore, be stated: measurements of length in which standard scale and the piece to be measured consist of the same material, and which are kept constantly at same temperature, are completely free of errors due to temperature, the values of length for the standard temperature of the scale are obtained without any reduction.

In the following table the principal materials for measuring scales of better quality and their expansion coefficients are given.

[1])On the question of standard temperature in engineering numerous papers have been published. Reference need be made only since 1918 to the volumes of Zeitschrift des Vereins deutscher Ingenieure, Maschinenbau, Werkstattstechnik, etc., but especially to the publications of the Committee on Standards of German industries (N D I).

Temperature Coefficients of Important Materials for Measuring Purposes.
Values in 0.001 mm for 1 m length and 1°C. increase of temperature.
All values must be considered as averages.

Aluminum	24	Magnalium	24
Lead	29	Brass	18.5
Bronze	17.5	Nickel silver	18
Iron	12	Nickel	13
Glass	8	Platinum	9
Jena 16III	8.1	Platin-iridium	8.8
Jena 59III	5.9	Quartzglass	0.5
Invar (nickel-steel with 36% Ni)	1	Quartz perpendicular to axis	14.4
Indilatans (Krupp)	1.6	Quartz parallel to axis	8.0
Nickel steel (58% Ni)	12	Silver	19
Iridium	6.5	Zinc	30
Constantan	15	Tin	30
Copper	17		

(Iron and Steel have practically the same expansion coefficient. An average a little more exact then given above is 11.5×10^{-6}. A hard steel casting has up to 14×10^{-6}, cast iron down to 9×10^{-6}.)

With respect to the foregoing, the following may be said: wood, celluloid and similar materials as ivory and bone, are considered only for scales of low accuracy as they are changeable and easily altered by external influences, but with care they stand up as can be observed with the familiar divisions of slide rules which give as is known from many experiments, a measuring accuracy of about 0.05 mm if manufactured carefully. For finer divisions, generally brass inlaid with silver is used because lines can be drawn extraordinarily well on silver. Unfortunately, it is attacked very strongly by the usual air in a laboratory. Suitably treated steel is almost as good. For both the changes of length which are in no case entirely excluded are fairly small during the course of years. Platinum is a very high-grade material for scales but often out of the question due to its price and used only for small scales or as a coating for other materials as it also permits drawing very fine lines. A very high grade material is 36% nickel-steel,[2]) called Invar in France. An equivalent material is manufactured in Germany by Krupp under the name of Indilatans. It is particularly conspicuous by the fact that its expansion coefficient is negligibly small, according to its composition, and approximately equal to 1×10^{-6} while the expansion coefficient of its two principal constituents is more than ten times larger. This expansion coefficient can by the way, be greatly changed by proper mechanical and heat treatment so that pieces can be obtained which are practically free from expansion or sometimes even have a negative expansion coefficient. From the point of view of measuring technique they possess the disadvantage that their variation with time is quite considerable and apparently the larger the smaller the expansion coefficient. Also the latter itself does not seem to be invariable. In certain cases, particularly for shorter scales, they are an excellent material. It is not easy to work but it can be very well polished.

The expansion coefficient of glass is given in the table as a certain average value. Glass is generally used only for small scales where its temperature expansion is immaterial. Quartz glass with its negligibly small expansion coefficient has also been used occasionally for high-grade standard rules, however, the drawing of the lines on it offers considerable difficulty. Crystalline quartz is indispensable for precision measuring purposes.

A few more words on iron and steel, respectively, as material for measures of lengths. It is that material, which is used industrially to the greatest extent, but which has certain disadvantages particularly when applied as end measures, and in fact, in those of the highest accuracy. On the other

[2]) This alloy contains mainly iron and nickel, and, in small amounts, according to the desired purpose, manganese chromium, traces of sulphur, and silicon.

hand it is very difficult to obtain grades of steel having a definite coefficient of expansion, and just this latter property for steel unfortunately varies within very wide limits. There are cases known where it was as low as 9×10^{-6}, but also as high as 14×10^{-6}. Even values with still greater spread occur occasionally. Besides, steel must be hardenable for making end measures; this has the disadvantage that stresses occur, which gradually disappear and then result in changes of length, consequently bodies of hardened steel have a tendency to change their length, if not very much, enough to make them of appreciable importance for industrial end measures in industrial laboratories. Hardened steel can be aged by suitable methods of tempering and thereby made more permanent in volume. A sufficient permanency from the measuring-technical point of view can, however, not be obtained in all cases with any degree of certainty. Soft, unhardened steel is much more advantageous for measures. The question of a steel of permanent volume for measuring purposes which can be only a pure carbon-steel has so far not yet been solved. The manufacturers of measuring tools have to take special care in the treatment of steel in order to obtain satisfactory measuring tools.

Concerning the shape of measures, this is entirely dependent on the application. Something on the shape of highest-grade measuring rods with X and U-sections was said in the introduction. In general, these shapes will not be used for usual purposes, but measuring rods with rectangular section will suffice, which, for many cases, are sufficiently accurate. If a chemical laboratory has at its disposal a measuring rod of rectangular section of 1 m length which is of high-grade manufacture so that its division can be considered correct to 0.01 mm it will be sufficiently equipped for all cases.

The question of supporting measuring rods has already been discussed. In addition it may be stated here, without proof, that in each rod two points can be found in which it can be supported without its length being changed. These points the location of which can be calculated are designated as *Bessels* points; they are each 2/9 of the length of the rod distant from the end. If the rod is supported in these points the rod apparently shortens between them and is lengthened in the free overhanging ends. Both effects are just counterbalanced.

Further, it must be noted that a scale can change its length if it is placed in a vertical position, that is, if such a measure, for instance, is used, together with a cathetometer. If, therefore, a correct scale is put in a vertical position on its end it will be shortened due to its elasticity, and it will be lengthened, for the same reason, if it is suspended by its upper end. If for measurements of length in the vertical direction only the total length of the scale is required these two changes can be compensated by fastening it in its center.

A vertically suspended rod of length l and weight p and of a material the modulus of elasticity E may be lengthened by its own weight. The unit of length of the rod close to the point of suspension is elongated by the weight P, in the center of the rod by $P/2$, and at its end by weight 0. On an average the unit of length is elongated by $P/2$. The length l is therefore subject to an elongation of $\frac{l\,P}{2\,Eq}$ (q is the section).

Iron has a modulus of elasticity of 20000 kg/mm², brass 9000 kg/mm². A scale of iron with the dimensions 1000 x 5 x 20 mm, weighs about 780 g, the same of brass about 860 g. If suspended vertically they are elongated

by their own weight by $\frac{1000 \cdot 0.780}{40000 \cdot 100}$ or $\frac{1000 \cdot 0.860}{18000}$ respectively, that is by 0.0002 mm or 0.0005 mm. In similar manner, a steel tape of 20 m length and 10 x 0.5 mm section, that is 780 g. weight, is elongated by $\frac{20000 \cdot 0.78}{40000 \cdot 5}$ mm = 0.08 mm. A load of 20 kg. fastened to the tape for stretching will elongate it by $\frac{20000}{20000 \cdot 5} \cdot 20 = 4$ mm.

The shapes of measuring rods differ according to their practical application. Starting from the longest scales the so-called measuring tapes for special purposes, may first be mentioned. In general, they are made of thin steel ribbons on which the division is engraved or etched. Sometimes the division points are marked by rivets. These ribbons are often so thin that they can be bent without difficulty and therefore also closely follow curves. Their principal field of application is geodetic surveying. They are made in lengths of 5, 10, 20, 50, and also more meters. If they are used for measurements care must be taken that they lie in a straight line as they naturally will be noticeably shortened if they sag on an uneven surface. For more exact measurements it is even necessary to stretch measuring tapes with a definite tension as they are easily elongated slightly due to their very small section. In many cases, therefore, their length holds good for a tension of 10 kg.

Such tapes are also made in shorter lengths, a few meters down to 1 m, in correspondingly smaller sizes and thinner sections. Such types are often very convenient if it is question of measuring lengths which do not lie in a straight line, as circumferences of cylinders, etc., where this tape can easily be made to closely follow the contours. If difficulties are encountered in measuring the diameter of a cylinder directly greater accuracy is obtained by simply measuring the circumference with the tape and calculating the diameter from it. But the following must be considered: The tape has a thickness of 0.5 mm. If it be put around a cylinder having a circumference of exactly 200 mm, the tape will indicate this. This means, of course, that the central layer, the neutral layer of the tape, is exactly 200 mm long. The layer with the divisions is elongated, the opposite side the length of which actually coincides with the circumference of the cylinder, is shortened. For a circle $C = 2 r \pi$. In the present case r is about 32 mm. The apparent shortening of the inner layer of the tape is therefore $2 \pi \cdot 0.25 =$ 1.57 mm. The circumference of the cylinder is consequently 198.4 m.

Measuring tapes of materials other than steel or nickel-steel are not used where accurate measurements are desired. But mention may be made here of long measuring tapes of 10 to 20 m of textile materials which in many cases may well be used to advantage and which are improved considerably by weaving them with wire without losing much of their flexibility.

The other shapes of measuring rods can be designated as fixed scales. In special cases they are made in lengths up to 10 m, generally 1 and 2 m lengths are standard. Generally they are of the practically convenient rectangular section, in many cases one edge is beveled, as in the known form of a ruler so that the divisions directly touch the underside.

Measures of this kind are manufactured in any length. In smaller lengths of about 10 cm and less they are usually designated as scales. The latter are extremely important from the measuring point of view since, as mentioned before, it is possible to meet higher demands for accuracy in

such shorter division than is otherwise possible. For scales, glass is often also employed for the material. This can be done in the shorter lengths as they are less liable to break. Quartz also is occasionally used. There is no doubt that the arrangement of a division on a transparent body often has a very great advantage. Otherwise, measuring rods of glass are only made for certain special purposes, they could very often be used to great advantage if the danger of breaking were not so great. The scales for the so-called mirror-reading instruments are, however, frequently made of glass as they can be artificially illuminated easily and uniformly.

The division of rules is generally in millimeters. A closer division is not practical though frequently divisions of 1/2 mm are made. The possible small increase of measuring accuracy which is, by the way, only quite insignificant, is completely counter-balanced by the greater difficulty in reading. This, of course, changes entirely if the measure is used with microscope reading. Special scales are often used in connection with microscopes of larger or smaller magnification. For instance, the microscope glass-scales may be mentioned which are placed in the ocular, and are visible together with the observed object, and serve to determine the dimensions of the latter. It offers no difficulties to make scales of any shape and length, which are provided with divisions of 0.01 mm. Divisions for measuring purposes with still closer lines are hardly ever made even for microscopic readings, although the practical possibility exists as frequently lattices for optical purposes are made which have lines 0.001 mm distance apart and less. For many divisions of scales, especially such as are used in connection with microscopes, the length of the sections is often of no importance as it is necessary to determine these separately in the individual cases. Take for instance the case of a microscope with ocular scale where the value of a division depends entirely on the magnification of the objective and the length of the microscope tube. It is obvious that the divisions of such a scale only are of value if the divisions are determined for a certain magnification of the objective and tube length. On the other hand, it is also necessary that such divisions be made absolutely uniform. For obvious reasons, manufacturers generally make such scales with strictly metric divisions to be able to also use them for other purposes.

Nothing more need be said on the application of such measures for measuring purposes particularly if it is possible to place the standard and length to be measured side by side to determine the length with the naked eye. The only correction which eventually need be made is the influence of temperature which has been discussed above and which within the usual temperature limits of the laboratory and for lengths of 1 m, amounts to only a few tenths of a millimeter. If lengths are measured by means of microscopes, that is with greater accuracy, temperature errors must, of course, be determined more accurately. This holds for the simple case of measuring the barometric pressures or other pressures with the cathetometer. In such cases it will be necessary to know the temperature expansion coefficient of the material of the measure and, of course, also that of the object, the length of which is to be determined. In the majority of cases the values in the table above will be of use. These are sufficient especially if one works within the narrow limits of temperature in the laboratory. Let us take the frequent case of a brass scale, it can be assumed with full assurance that its expansion coefficient is $18.5 \cdot 10^{-6}$ for 1 m and 1°C. and that, with greatest probability, this value is not in error more

than $2 \cdot 10^{-6}$, very likely even not more than $1 \cdot 10^{-6}$ mm that means that for a length of one meter and with the usual laboratory temperature fluctuations of a few degrees no greater errors can be committed by this assumption than 0.01 mm, very probably not more than 0.005 mm, values which are almost always insignificant.

In general, the length of a measuring rod, i. e., the distance between its end lines is represented by a formula about as follows:

$$l_t = l_o + \alpha\, t = 1 \text{ m} - \delta + \alpha\, t \text{ or}$$

$$l_t = l_o\,(1 + \alpha\, t) \text{ or}$$

$$l_t = l_o + \alpha\,(t - 20^\circ).$$

Therein, α denotes the expansion coefficient of the measure and t its temperature at the time of measurement, while l_t and l_o respectively, are its true lengths at the observed temperature t and a standard temperature, for instance, 0° or 20°. With such a formula the length of a measuring rod for the desired temperature can then be calculated with sufficient accuracy, and, what is also very important, the lengths of parts of the rod. If we assume for illustration purposes the case that we make a very accurate determination of barometric pressure by means of a brass scale which is correct at 0° and has an expansion coefficient of $18.5 \cdot 10^{-6}$. With the cathetometer the barometric pressure may have been read to be 763.28 mm. We must now determine what the true level of the mercury column is at the prevailing observation temperature of 19.5°C. (The expansion of Hg will not be considered.) The total length of the scale can be represented by the equation $l_t = l_o + 18.5 \cdot 10^{-6}\, t$ m

or for the given temperature

$$l_t = l_o + 18.5 \cdot 10^{-3} \text{ mm} \cdot 19.5 = l_o + 0.361 \text{ mm} = 1000.361 \text{ mm}$$

under the assumption that the scale is absolutely correct. Its total length is, at the observation temperature, 0.361 mm too long, for the length of 763.28 read therefore too long by

$$0.361 \cdot \frac{763.28}{1000} = 0.275 \text{ mm}.$$

The true height of the Hg column of the barometer is, therefore, not 763.28 mm but $763.28 + 0.275 = 763.55$ mm. This is the true length of the mercury column of the barometer if we had compared it with a measuring rod whose length is independent of temperature and gives exactly the true length. The conversion of the mercury column to an observation temperature of 0°C. will be discussed later.

2. Verniers

The means for measuring lengths so far discussed have been restricted by the assumption that the scales are read with the naked eye without any other help. We will now pass over to a brief discussion of such measuring apparatus which facilitate such readings or permit carrying out finer measurements. We pass, therefore, from the measures of length proper to the measuring apparatus for lengths. At first, two expedients will be treated more in detail which are especially important, namely the vernier

and the use of screws for the measurement of lengths.

The vernier is an extremely widely used expedient to read scales more accurately. If we have a scale divided into millimeters a vernier is called an auxiliary division which is made so that, for example, 10 uniform divisions of this vernier correspond exactly to nine divisions of the scale Verniers of 20 or 25 and 50 divisions are also made in the same manner as the vernier of 10 divisions. There 19 divisions of the principal scale correspond to 20 divisions of the vernier, or 24 to 25 and 49 to 50, respectively.

As an illustration, the most simple vernier of 10 divisions may be explained (Fig. 21). If the zero line of the vernier coincides with the zero line of the principal scale, the tenth division of the vernier coincides as required with the width of the scale. That means that division 1 of the vernier has a distance of 0.1 mm from line 1 of the scale, division 2 of the vernier a distance of 0.2 mm, etc. If, therefore, at any other position it is found that, for instance, line 4 of the vernier just coincides with any line of the principal scale, it is clear that the zero line of the vernier must be 0.4 mm distant from the corresponding line of the scale. In other words, if a given distance is to be measured, the one end of this distance is made to coincide with the zero line of the scale, the other end will, of course, usually fall between two divisions of the scale. It is quite possible to estimate approximately how many fractions of a millimeter the still protruding length beyond the last line has. If one is, however, not skilled enough, the use of a vernier is more advantageous. The vernier is put at the end of the distance in such a way that its zero line coincides with the end of the former, and read. For instance, the seventh division coincides with a division of the principal scale. Thus the vernier gives directly by its reading that the length beyond a whole millimeter is equal to 0.7 mm. The number of whole millimeters can, of course, be read without any difficulty.

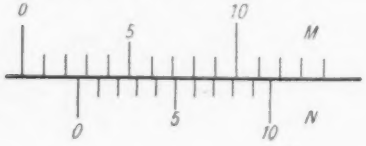


Fig. 22 (*below*). Twenty-five Division Vernier (M Main Scale, N Vernier; Reading 6.76).

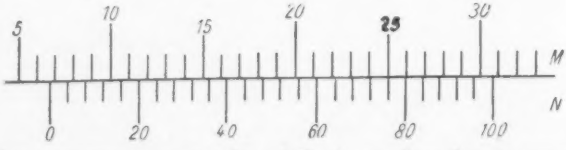


Fig. 21 (*above*). Ten Division Vernier. (M Main Scale, N Vernier; Reading 2.6

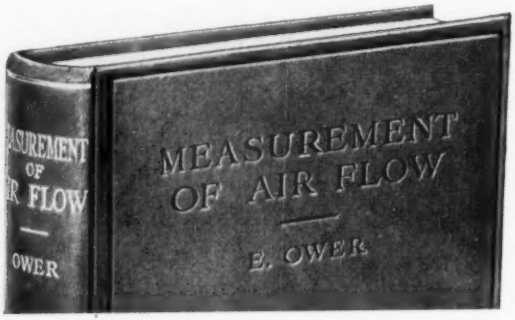
This method of measurement, somewhat difficult to describe, is very much simpler in practice. At this opportunity a very important simple measuring instrument may be discussed which makes through use of the application of a vernier and which is of quite extraordinary advantage for many measurements and is actually used in practice in innumerable cases. It is the so-called caliper. It consists in principle of a scale carrying on one end a rigid leg perpendicular to the direction of measuring. A sleeve slides over the scale which is easily movable and can often be clamped to the scale by a screw and carries a similar measuring leg. The inner jaws of the two measuring legs are shaped either as broad faces or as sharp edges, but in any case so that they touch each other along their whole length when they are brought together so that the line of contact is at

right angles to the scale. The latter has a millimeter division and the sleeve a division of the vernier so that the zero line of the vernier coincides with the zero line of the scale when the legs are close together. The caliper is a special instrument for measuring thicknesses. If a wire, the diameter of which is to be measured, or any other object is placed between the measuring legs and the latter moved toward each other until they hold it tightly, the zero line of the vernier will in general, lie between two lines of the division of the scale. The last principal line of the division will, therefore, indicate the thickness of the object in whole millimeters, to which, then, must be added the distance of this line from the zero line of the vernier. The latter can be determined, exactly as explained before, by finding which line of the vernier coincides with a line of the scale, and if this is, for instance, line 8 of the vernier, we know that 0.8 mm must still be added to the number of millimeters read on the scale. It may be noted that it is not at all necessary to determine which line of the scale coincides with the line on the vernier. On the scale only that line need be read which immediately precedes the division of the vernier.

If it is a question of a vernier with 20 divisions which is frequently the case, that is 19 divisions of the principal scale equal 20 division of the vernier, the considerations are absolutely similar. The difference of the distance from line to line is then not 0.1 mm but 0.05 mm, i. e., while the vernier described above reads to 0.1 mm, the latter gives results to 0.05 mm, or a coincidence of line 6 of the vernier with the principal scale means a reading of 0.3 mm, 16 = 0.8 mm, 13 = 0.65 mm, 7 = 0.35 mm, etc. Very often the numbering of the vernier is made so as to eliminate the division by two and to read the fractions directly. (Fig. 22 is an example of a vernier with 25 divisions.)

The vernier with 50 divisions, finally, gives readings to 1/50 = 0.02 mm. Here also the numbering is generally made so that the fractions are read directly, i. e., a reading of 37 corresponds to 0.74 mm, of 21 to 0.42 mm, etc. It is of course assumed that the division of such as vernier is very accuratein itself. Usually a magnifying glass must be used to determine with certainty which two lines coincide and if the division is of only mediocre workmanship. The coincidence will not always be without doubt but that line, must be selected which apparently seems to coincide best. A vernier of fifty divisions is only of value if it is accurately made, which can be done without difficulty.

The same divisions of a vernier are in many cases also used for circular divisions where, of course, the arrangement and principle of its use fully agree with what has been said above. How the vernier is arranged in this case can not be covered by a general statement as with the multiplicity of types and the many variation possibilities, the arrangement will change from case to case. Let us take an often used case, that the principal scale has a division of 1/2°, then very likely a vernier of 30 divisions is used which correspond to 20 divisions of the principal scale that is to an arc of 14.5°, an interval at the vernier is then 1/30 of the principal interval, i. e., one minute (= 1/30 of 1/2°). In other words, if we read 17 on the vernier, we must add 17′ to the reading on the principal scale, however, it must be noted whether the zero line of the vernier stands between the lines for the full degree and 30′ or between 30′ and the next full degree. The reading would correspond to either 17 or 47′. If the principal scale is divided into 1/4° which is often the case, this would correspond to 15′. Here also a vernier with 30 divisions can be applied, this then gives readings corresponding to half minutes. Further possibilities of divisions will not bediscussed.



The Measurements of Air Flow

By

E. Wwer, B. Sc. (Lond.), Hons. I., A.C.G.I.

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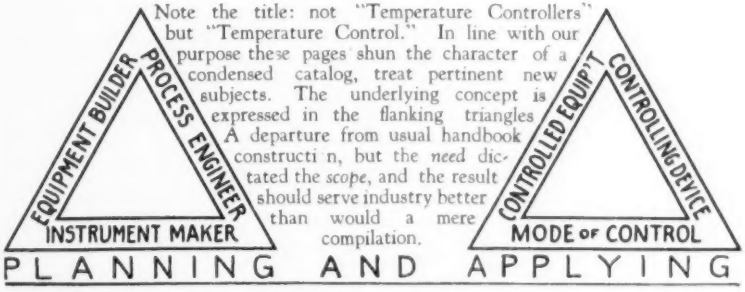
The Engineer's Handbook of Industrial Instruments

M. F. Béhar*

CHAPTER II
Industrial Temperature Instruments
(*Concluded*)

Part 5—AUTOMATIC TEMPERATURE CONTROL



Note the title: not "Temperature Controllers" but "Temperature Control." In line with our purpose these pages shun the character of a condensed catalog, treat pertinent new subjects. The underlying concept is expressed in the flanking triangles. A departure from usual handbook constructi n, but the *need* dictated the *scope*, and the result should serve industry better than would a mere compilation.

1. General Considerations

A thermometer or pyrometer indicates what the temperature *is*.

A recorder shows what the temperature *was*.

An automatic temperature controller deals with the future: "Set it and forget it"—the slogan launched by one pioneer controller manufacturer long before the World War—aptly sums up its liberation of manpower for more productive occupations.

Every temperature controller starts with a thermal system. Hence an acquaintance with the characteristics of the groups, classes and types of temperature *measuring* instruments is required for an adequate understanding of automatic temperature control—controlling instruments, controlled devices and other elements of temperature control systems. Since indicating thermometers and pyrometers have been dealt with in parts 2 and 3 of this chapter, their advantages, limitations and other characteristics need not be dwelt upon here. The thermal systems embodied in all temperature controllers obey the same physical laws as are obeyed by the corresponding indicating thermometers and pyrometers, but practical requirements have imposed far different forms in most cases. It is of interest that the *difference* between a temperature indicator and the corresponding thermal system of a temperature controller (for the same given range) is usually small for high temperature applications, and becomes greater as the range lies lower. Thus in quickly glancing over the entire field of temperature control, one observes that pyrometric control systems start off with indicating and recording pyrometers to which a few extra

*Engineering Editor

parts have been added; whereas in the "hot-water" working ranges we meet a great variety of thermal systems which, while they have bulbs and connections identical with those of the indicators and recorders, differ widely inside the instrument case on the panel board (when there is anything at all resembling a case); and finally, in the field of refrigeration control, we come across specially designed thermal systems which, while employing one of the several applicable principles of thermometry, resemble thermometers as little as a bell-ringing push button resembles an automatic motor starter.

Since automatic temperature control won noticeable acceptance in industry with the turn of the century, the trend toward simplification—*where temperature indication was not required of the controller*—resulted in a variety of inexpensive thermostatic devices. These invaded the domestic field, whereupon competition arose and brought about even greater simplification. It was discovered long ago that whereas a temperature indicating instrument must be accurate over its entire range, the sensitive element of a thermostat need only be "accurate" over a very narrow range. The on-and-off mode of control of the simpler devices further reduced the number of design factors. Quantity production led to standardization and an ever-increasing number of applications have been discovered, developed and exploited in the home, on the farm and in the office, as well as around the plant.

A parallel line of development combined the sensitive element with the actuating element: the same part which responded to the temperature turned the heat on and off as required. This simplification has reached what may be its triumphant climax in the Westinghouse Klixon for preventing over-heating of electric irons—a bimetallic disk which suddenly bulges at a certain temperature, with sufficient strength to throw the cut-off switch. If this device does not hold the record for simplicity, then perhaps the glory belongs to a tiny hollow brass disk which, when dropped into a socket before screwing in an electric bulb, causes the latter to blink.

On the other extreme, we might mention certain systems of temperature control for blast furnaces and other very large and very important industrial applications—but we do not imply that these constitute the climax of complexity and cost.

At any rate such examples show the considerable and ever-growing extent of the field of automatic temperature control—a subject which could fill volumes. We can only deal with the *industrial* process temperature controllers—with the devices themselves without attempting to touch upon their specific industrial applications—and very sketchily at that . . . and *control* must be discussed before *controllers*.

Another thing which strikes one who travels his glance over the field of temperature control, starting with high temperatures and ending with refrigeration, is that the number of *specialized* and *standardized* thermal systems and relay systems is the greatest in the middle, tapering off at both ends. This is in exact accordance with the "penetration" of temperature control in winning the confidence of industry. As long ago as 1919, Fairchild and Foote of the Bureau of Standards, addressing the A.I.M.M.E. on "High Temperature Control," declared that "the greatest progress has been made in those industries in which the lower temperatures are used, particularly below 500°C. In this lower range automatic control has been highly developed."

Suitable Equipment Required

This significant utterance, still applicable today, may be paraphrased; and it may be said that the development of automatic controllers is bound up with the development of automatic control. As in other fields of invention, the device which is ahead of its time can make little headway. Great as has been the extension of temperature control in industry, it is in its infancy, and its adolescence waits upon the growth and manifestation of a greater interest on the part of precisely that group of industrial engineers who would reap its greatest benefits. Let us not forget that there is a limit, after all, to the mind-reading ability of the instrument maker and to the power of advertising and salesmanship. The further development of automatic control and of controllers demands, first, a greater temperature consciousness on the part of prospective users of temperature controllers in industry; second, the granting of a freer entrée to instrument men by the former . . .

—and, third, a more receptive attitude on the part of the equipment manufacturer. It is high time for builders and manufacturers of furnaces, kilns, melting pots and tanks, lehrs, ovens, boilers, kettles, stills, towers, vats and of all other diversified industrial equipment, to realize that some among them are holding up the procession. It is high time for all to follow the example of a few who make "controllability" a part of design routine.

Every reader of this Handbook probably knows of some temperature control installation which was turned off or disconnected "because it did not work." The chances are that the controller was not given the proper opportunity to fulfil its mission, the reason being possibly that it was abused and probably that the equipment on which it was installed was not suitable for its application. Articles on automatic temperature control frequently appear in industrial publications and their authors are prone to make the general statements (1) that any piece of equipment which cannot be controlled by hand cannot be controlled automatically—which is correct—and (2) that where temperature can be controlled manually it can be controlled automatically—which is wholly untrue with reference to the very applications which today still resist the conquest of automatic temperature control. Is it not a fact that in the case of several metallurgical processes *manual* control really means *visual* control, and that the furnace builders stick to their designs which were developed for the benefit of the old-time pre-pyrometry metallurgists who worked by eye!

Such furnaces will have to be re-designed by or with the assistance of three groups of experts: (1) specialists in the proper application and location of thermocouples and radiation receivers which "feel" the temperature which is to be controlled; (2) specialists in the application of power-driven regulating devices; and (3) specialists in the combining of these two elements—engineers who might be called the liaison officers experienced in the performance characteristics of temperature control applications.

Finally, we must not forget the operating man's viewpoint. If the equipment is such that temperature control is not really automatic, he will be the first one to complain . . . or make trouble.*

*Excellent discussions of design factors with regard to high temperature distribution and control are found in R. M. Keeney's article "Form of Furnace for Heat Treatment" (*Metals and Alloys*, July, 1930), and in M. H. Mawhinney's paper "Tempeeature Distribution in Combustion Furnaces" presented at the September, 1929, Cleveland meeting of the A. S. M. E. These discussions show the obstacles in the way of applying automatic temperature control to furnaces where gradients exist, making it difficult to select the one location where the temperature is representative and where at the same time it is indicative of both changes in demand and effects of changes in supply.

Proper Installation Required

Next to the application itself, which sometimes precludes automatic control and always limits the number of suitable temperature control hook-ups, the manner in which control is applied is a prime consideration. In many cases the man in charge of a process may cry in vain for close control, because even if he selects a type and make of automatic controller which, with its appurtenances, is likely to give him fairly good results, the proper installation of this temperature control system might require that the instrument company's engineer spend an entire week on that application . . . after spending months studying the process. That is one reason why automatic control has not yet been adopted for certain processes, especially for certain high temperature processes. Not only have some furnaces not yet been sufficiently modified for the application of temperature control devices, as mentioned above, but the furnace builders, the instrument makers, and the metallurgists have not yet pooled their knowledge sufficiently to apply control in a scientific way to many furnaces which *could* be controlled. Instrument sales and service engineers cannot be expected to possess intimate knowledge of all temperature processes and of all types of temperature process equipment. Team work is required. Team work means "getting the signals," means understanding one another. It is too much to expect of processing equipment builders and users that they learn the language of the instrument fraternity. They need not even learn much about controllers. But they must understand *control*. Especially the industrial process man: his job—let it be repeated—is the conquest of variables, which is another name for control of all conditions. Temperature being an important condition he cannot afford to "leave it to the instrument man," much less to *any* instrument salesman. He must be able to define what he wants in the way of control.

A good yatchtsman can sail a sloop, ketch, yawl, schooner or square-rigger without knowing a thing about shipbuilding; a good driver can take anything from a Mack truck to a baby Austin through crowded traffic without ever having lifted a hood . . .

2. Possible Classifications of Industrial Automatic Temperature Control Devices and Systems

The above heading suggests one classification—the word "Industrial" excluding domestic devices.* Even restricting our scope to the industrial temperature controllers, space limitations prevent their being treated exhaustively as mechanisms; there is a better use for this space than encyclopaedic cataloging.

Another possible classification is by the usual designations and what they stand for, but the nomenclature has not been standardized and as a matter of fact it would be hard to draw lines separating thermostats, heat regulators, temperature regulators, automatic temperature controllers and automatic temperature control systems—not to mention devices called by other names.

Another classification is into non-indicating, indicating, and recording automatic temperature controllers, these designations being self-explanatory.

*As a matter of fact, some of these—especially those that come within the jurisdiction of and comply with the various electrical and mechanical standards sponsored by the AIEE, NEMA, NELA, Underwriters' Laboratories—are better designed, better constructed, operate better and sometimes necessarily cost more than some of the simpler forms of industrial heat regulators.

Usages vary somewhat in the application of modifications of these names. In the thermometric range we find such terms as "indicating controller" and "recorder-controller," both of which are self-explanatory. In the pyrometric range, "controlling pyrometer" is generally understood to mean an instrument which also indicates, while "recording controller" and "controlling recorder" are both used—never "recorder-controller." "Controlling potentiometer" is the usual designation when the system is based on that class of instrument, the reason being that potentiometers with control features are applicable without modification for the regulation of other conditions beside temperature: humidity, flow, level, pressure, gas analysis, pH, speed, light, etc.

"Self-contained" and "distance" or other such terms suggest a simple and practical distinction between instruments located at the point of application and those with connecting tubes or couples running from the bulb or couple to another element of the system; or else the distance feature may refer to the operation of a valve at a distance from the instrument case which may be located on a panel board.

One logical classification is into self-operating instruments or appliances or *devices;* and control *systems* which utilize relays. By "self-operating" is meant that the primary element responds to temperature with sufficient force to operate a valve, damper, etc., for controlling temperature. If the primary element operates a pilot valve or a switch the controller belongs to the relay class. The "instrument" proper forms part of a hook-up which must be considered as a whole: the instrument "governs" the power which "controls" the temperature.

This suggests a classification according to form of power. Such forms will be discussed below but it will be hard to follow a definite classification because some systems would belong to two and even three classes. For example, a primary element may actuate an air valve relay which operate an electric control which in turn operates the energized final device.

"The energized final device"—this does not mean the valve or damper but the device which operates it; and here we have still another basis for classification: Diaphragm, solenoid, cylinder-and-piston, electric motor, etc.

And last but not least, a classification of the valves and other medium-controlling appliances. Certainly not least, because this final element of the temperature control system often determines the choice of the others.

To tabulate all the possible combinations in a comprehensive and systematic way would be both tedious and useless. An idea of the number of possible hook-ups may be had by multiplying the number of types of primary elements (about 20) by one-quarter of the number of classes of relay methods (about 8), multiplying the product (about 40) by one-quarter of the number of forms of power devices (about 20) and multiplying this product (about 200) by one-quarter of the number of varieties of finally operated valves (about 400). We get something like 20,000 possible combinations, and only one-quarter of the number was used at every step of this process.

Or, to put it in another way, you may start with any one of the 20-odd types of primary elements, have it actuate one of a choice of two (out of 8) relay systems, then select any one of five (out of 20) power devices capable of operating any one of 100 (among 400) valves.

Omitting the valves we have the very conservative number of 200 wholly different types of automatic temperature controllers. We could even call

them classes because they would all be mutually exclusive. And all this without mentioning the possibilities in the way of direct and reverse action at each step—which gives us $200 \times 2 \times 2 \times 2 = 1600$.

3. Selecting a Controller

Probably a greater number of combinations or hook-ups have actually been made and installed by scores of manufacturers. Not all of them have been standardized and cataloged. Nevertheless, after many nights of browsing through piles of catalogs, the author concludes that the number of different combinations actually on the market runs into so many hundreds that for any "average" industrial application—say a steam-heated application—the choice of hook-ups (regardless of make) is bewildering. Therefore, it would seem from a purely logical standpoint that the one best course for an industrial engineer to follow would be somewhat along these lines: First, make sure that the equipment can be controlled. Then,

1. Determine the size of steam valve.
2. Select the form (which may mean make) of valve having the best characteristics. (All worth-while manufacturers have plotted them.)
3. Select the class of valve-operating device which has the most applicable operating characteristics with reference to the steam supply and the valve characteristics.
4. Having taken care of the end, go to the beginning and select the most suitable class of primary element for the temperature range.
5. Within this class select the most suitable type, form, material, size, etc.
6. Select the most suitable connective mechanism between your primary element and your power device.*

This is a logical or "ideal" procedure for the engineer to follow. If he is not himself an "ideal" engineer he may have to devote a week or so to it. A flesh-and-blood engineer who has to earn his bread-and-butter in a plant seldom has a chance of doing it—except perhaps where his problem is to standardize on the best control for a large number of identical pieces of apparatus. Splendid results have been achieved in some such cases: There are on the market various makes of heaters, kettles, and dozens of other standardized pieces of processing equipment which are furnished complete with properly applied automatic temperature control. Back of each is the story of an earnest engineer who may not have studied the details of many controllers but who certainly understood what was required in the way of control. Even here the question of *price* will influence his selection and the question of *service* may make him put up the whole problem to one manufacturer of complete temperature control systems.

Price and Service . . . we must recognize the existence of these powerful considerations and their weight in commercial reasoning. Engineering reasoning, however, arrives at the inevitable conclusion that perfect control is an unattainable ideal. This applies not only to temperature control but to all regulation problems and no doubt it is an old story to the engineering reader. The idea is that automatic control must start off with a primary element responding to departure from normality. This well-known principle implies that the one best temperature cannot be maintained constantly. The engineer's job is to conquer variables. If he has

*This does not preclude self-operating controllers. Engineering analysis may arrive at the conclusion that it is best—all things considered—to have the primary element actuate the valve.

done so before the installation of any thermostatic system, the recorder will show an even line and the controller will not be needed. In practice this state of things never exists because neither the supply of B. t. u's nor their consumption can ever be exactly equalized in order to maintain the proper temperature.

Maintaining the optimum temperature is not a case of balancing static forces. On any temperature apparatus we have an incessant flow and transfer of heat. The "driving" comparison throws much light on the subject: When you wish to maintain a speed of exactly 40 m. p. h., you keep your eye on the speedometer and expertly bear down on the accelerator. When you climb a grade, you have to increase the flow of mixture through the manifold; and on a downhill you sometimes can coast with the throttle almost shut. No matter how keen your eyesight or how quick your foot muscles, a recording speedometer would show a slightly saw-tooth record. You act only when there is a departure from normality. You never can maintain a speed of exactly 40 m. p. h. but you can, depending on the degree of your skill, maintain 40 ± 0.2 m. p. h., or 40 ± 0.6 m. p. h. In like manner no controller can hold at the exact optimum temperature. It can only hold "within" so many degrees, as the expression goes. What is called perfect control is simply very close control.

4. Modes of Control

Here ends the car driving comparison familiar to many engineers. Let us continue it: When you come to a hill you "step on 'er all the way to the foot board." This is something which most classes of automatic temperature controllers *cannot* do and in fact are not designed to do. A sudden extraordinary increase in the demand is *not* automatically met with a corresponding sudden and extraordinary increase in the controlled supply. All but a few (and rather elaborate) classes of temperature controllers are inherently and designedly incapable of meeting *both* small and large variations. And when we say controllers we mean the assembled elements of control systems. *Each* element has its own operating characteristics—chiefly *amplitude* characteristics and *time* characteristics. All of these together make up the "behavior" of one control system. The study of temperature control is primarily a study of the behavior of various control systems—the study of the various *kinds* of behavior. This subject, by the way, far from being theoretical, is the most practical of all for the practical man to acquire. Just as in selecting men for jobs, not the height and weight but certain qualifications must be kept in mind, so in the application of temperature control, the study of various classes and makes of temperature controllers with reference to their appearance and construction is of little value to the engineer who lacks a clear idea of *performance standards*. For this purpose we have had to coin the expression "Modes of Control" because the familiar expression "operating characteristics" is habitually applied to individual regulating systems.

Again reverting to automobiles, the terms "pick-up," "roadability," "mileage," "ease of steering," "flexibility," etc., are mostly comparative, mean much to the experienced motorist, not much to Mrs. Newlywed driving her first car, and very little to people who have never taken the wheel. These terms are loosely grouped under "performance"—which means one thing to the truck fleet owner and quite another to the pleasure driver. "Performance" of controllers (or of one controller) has reference

TYPICAL INDUSTRIAL SYSTEMS OF THERMOMETRIC

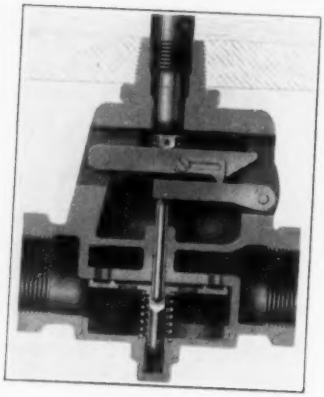
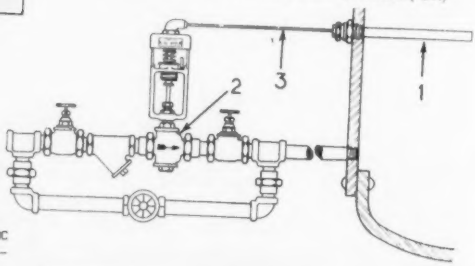


Fig. 101. Rod thermostat. Primary element acts also as power element which operates the fuel supply valve —in this case gas. (Note, by the way, that by substituting a smaller valve this thermostat would become a pilot valve controller—and as a matter of fact the same manufacturer makes air-, gas- and water-operated temperature controllers of such construction.) The primary element is a tube of metal having a large coefficient of expansion, inside which is a transmitting rod with low coefficient. Two adjustments: (1) a stud on which the inner rod abuts and which determines the valve opening for the desired temperature; (2) a lever arrangement whereby any definite motion of the inner rod produces an adjustable motion of the valve disk by positioning the link between the two horizontal levers. (*Robertshaw Thermostat Co.*)

Fig. 102. Self-operating temperature controller. Bulb develops pressure expanding bellows directly against stem of controlled valve. Note steam strainer, by-pass, and other details of typical installation for steam heat application. (*Consolidated Ashcroft-Hancock Co.*)



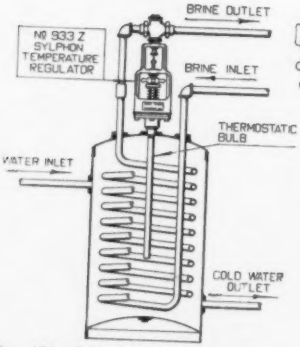


Fig. 103. Self-operating temperature controller installed on a refrigerating application. (Bellows at higher temperature than bulb.) Direct-connected type. Adjustable temperature setting. (*The Fulton Co.*)

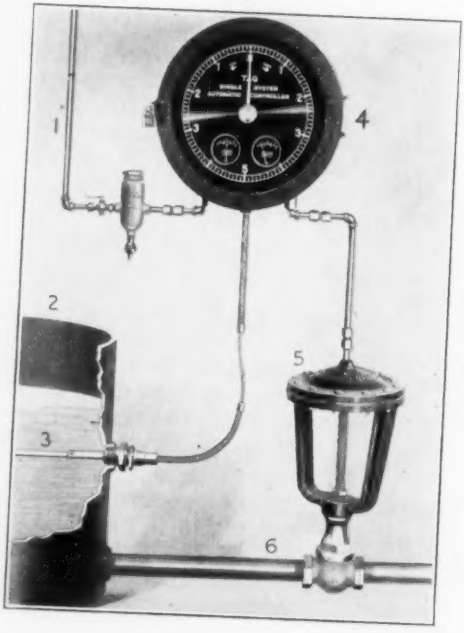


Fig. 104. Complete installation of air-operated ("throttling") temperature controller. 1—Compressed air supply (must be even pressure). 2—Apparatus under control. 3—Bulb (in this case vapor-pressure class.) 4—Controller proper. Non-indicating type. Note setting dial, air supply gage, and controlled air gage indicating operation of diaphragm-motor. 5—Diaphragm-motor valve operated by air relay in controller. 6—Heating medium—in this case steam. (*C. J. Tagliabue Mfg. Co.*)

AUTOMATIC TEMPERATURE CONTROL
PYROMETRIC

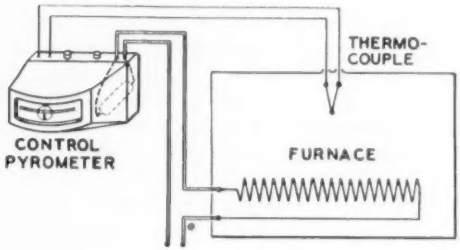


Fig. 105. Typical controlling pyrometer installation in which no relays are required in addition to the mercury switch within the instrument. Auxiliary power is required to trip the mercury switch. (*Republic Flow Meters Co.*)

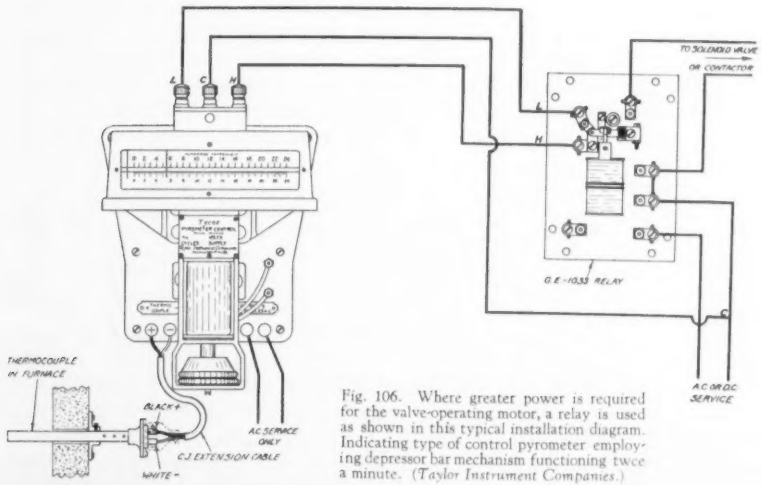


Fig. 106. Where greater power is required for the valve-operating motor, a relay is used as shown in this typical installation diagram. Indicating type of control pyrometer employing depressor bar mechanism functioning twice a minute. (*Taylor Instrument Companies.*)

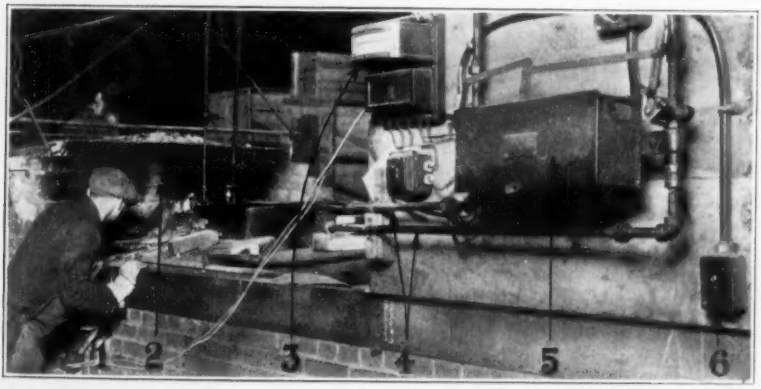


Fig. 107. This photograph shows all the elements of a complete pyrometer installation. 1—Thermocouple 2—Furnace. 3—Control pyrometer. 4—Air and fuel supply. 5—Valve-operating mechanism. 6—Electric power supply. (*Brown Instrument Company.*)

to the results obtained in labor saving, fuel saving, uniformity of processing, etc.—*what* various controllers do to justify their installation. "Mode of Control" has reference to The One Best Way of maintaining The One Best Temperature—*how* various controllers do it; hence how one does it better than another; hence how to select the most suitable.

Before coming to temperature controllers, therefore, it is necessary to afford a glimpse into the art of specifying and applying control, and getting the most out of it. "Art" and not science, because the body of knowledge on the subject is widely scattered—much of what there is of it jealously guarded, and what little has been made public has been not only fragmentary but highly particularized and narrowly applicable. One can only hope at this time to give a summary.

Inasmuch as the subject at hand is essentially one of behavior, it will greatly simplify matters to personalize the controller. Instead of an instrument or elaborate system, let us have a *man* (as before the application of automatic control) and let us study his behavior under various circumstances—in a number of "cases," which are sometimes typical and sometimes merely of interest in bringing out various points. Indeed, let the reader take the part . . . Throughout this discussion you are the automatic controller. The mode of control in each case is not so much what you do as how you do it—rapidly or slowly, completely or partly, correctly or incorrectly.

The personification of an automatic device is by no means original with this author. "Robot" articles have abounded in periodical literature since the first American production of the Capeks' play nine years ago. And, in the Wilson-Maeulen Co. booklet on the application of control to industrial furnaces we find the following:

"For Automatic temperature regulation we have——

"First—Automatic Control instruments . . . Thus we have the equivalent of human observation and human decision.

"Second— . . . power operated devices . . . Thus we have the equivalent of human manipulation."

To make the discussion apply to the greatest number of installations, let us assume a piece of apparatus heated by only one source of B. t. u. supply—a steam line. You don't have to feel the temperature by hand; a dial-indicating thermometer faces you. You keep your eyes on it and your hand on the steam valve. An ideal recording thermometer—which you can't see—writes down the exact story of the results of your valve manipulation You resolve to hold at 200°F. Therefore, when you see the pointer climbing above 200°, you admit less steam or no steam at all.

Simple? On the contrary; we already have material enough for a whole book. Consider the following factors:

1. The *sensitivity* of the dial thermometer. If its pointer remains stationary unless the temperature *of the bulb* rises or falls one full scale division (never mind for the present the value of each scale division), it will be of less help to you than an ultra-sensitive indicator. The best you could hope for is a sawtooth temperature record, the depth of the teeth being at least *two* scale divisions—unless you "know when to stop ahead" as discussed under Case 2.

2. The *time-lag* of the thermal system of the indicating thermometer on which you depend is another important factor. Assume it is exactly one minute. This being a loose definition, assume that a sudden change of, say, 5° in the temperature *surrounding* the bulb has absolutely no effect for thirty seconds, that the pointer then starts to move, first fast, then

slowing down so that at the end of the full minute it will have stopped at the correct indication. Obviously you will be forced to lag behind the actual temperature. A great deal now depends on your judgment. Without going into details it is obvious that you must know when to stop. If you admit too many B. t. u's when you see the temperature drop, and hold back the supply too long when the pointer rises above 200°, the record will resemble a scenic railway; but if—after many tests, of course—you acquire the knack of stopping your corrective measure before the pointer goes back to 200, you can produce a record which for many industrial applications will be quite satisfactory. (Some controllers embodying heavily protected bulbs or thermocouples, can be so adjusted, within satisfactory limits.)

3. In the preceding case it was assumed that some processing condition suddenly changed the temperature, and that this condition very kindly refrained from "repeating." Naturally, something may send the temperature around the bulb up 5° for several seconds, at the end of which brief time the temperature around the bulb will return to normal. If the thermal system is altogether sluggish (combination of lack of sensitivity, and time lag) you will rather be up against it. You may decide to "wait and see." You may deliberately impose on yourself a sluggishness equal to or greater than that of your exasperating indicator.

4. Or else, you may take no notice of *slight* departures from 200° and you may decide to act only when the pointer has reached a certain distance on either side of the setting point, *and continues to travel.* In any event, knowing about the time lag, knowing that the pointer comes to rest one full minute after a 5° change in the temperature, you will decide that you should never do anything when the pointer *begins* to move.

5. Or else again, you may recognize the *rate* at which the pointer swings once it gets started, having observed that it varies with the extent of the sudden departure from normality—and the consequent extent of the necessary corrective action.

6. Whatever you decide to do under the circumstances, another man will probably decide differently. The psychological reactions of different individuals differ. (Likewise the reactions of differently designed control systems differ. By the same token the reaction of any fully *adjustable* control system can be varied in response to or in accordance with the direction, extent and speed characteristics of behavior of the thermo-sensitive element.)

7. The next consideration is your own speed of reaction. Having settled the question of at which point you are to *decide* to act, it is now of interest to know how long it takes you to act. The reaction times of different individuals differ. (Likewise in different control systems. It must be mentioned at this point that instantaneous reaction is not always necessary; nor is it always desirable; and in some cases it may cause too much consumption of power, too much wear on moving parts, and other troubles in the control system—apart from its undesirability with reference to the process.)

8. We must now consider the nature or extent of your manual action. Assume your hand is on a gate or balanced valve offering no resistance, and operated by a long lever so that the vertical travel of your hand is ten inches from full opening to dead shut. In order to simplify the discussion

let us forget that you are watching a dial thermometer. Let us assume you are watching a set of two signal lights: a red light which flashes while the temperature surrounding the bulb exceeds 200° and a green light which flashes when it falls below 200°. Assume also that there is no time lag either in the signal system or in your nervous and muscular systems. You may follow one of *two* modes—no more:

(a) Open the valve wide when the green light flashes; close it entirely when the red light flashes. What happens now? Obviously a sawtooth record. But how serious? That entirely depends on the size of the valve, on the steam supply and on the heat demand. Here we must refer to "process lag," the time lag over which you have no control.

This is not the familiar "on-and-off" mode of control, in which there is a definite interval or "differential" between the two temperatures at which the on and the off actions take place. In 8(a) above, there is no interval: The source of heat is full-on as long as the temperature exceeds the setting point by any number of degrees or even by the fraction of a degree; and it is entirely off when the temperature of the controller bulb is anywhere below the setting point.

The heat capacity of the application is an important factor here. Where it is large with respect to the heat supply, on-and-off control will not produce an objectionable sawtooth record if the primary element is sensitive and if the time lag of the controller is negligible—as is assumed in this particular case. In addition, the temperature of the primary element must really be representative of the apparatus temperature.

(b) As long as the red light flashes you bear down on the lever at a definite rate of motion; eventually the green light will flash, and then you reverse the direction of the motion of your hand, so that while the green light is flashing you are opening the valve wider and wider. Eventually the red light will again flash, whereupon you will again gradually decrease the B. t. u. supply—the alterations being repeated over and over. It sounds better than (a) and it actually is a better mode of control. (In practice, incidentally, it *costs* more.) Occasionally you may alter the rate of motion of your hand, until you determine that rate which will produce the least objectionable sawteeth.

9. An improvement or elaboration of this signal system (which makes it look more like familiar devices) now takes the form of a light between the red and green, which flashes while the temperature surrounding the bulb is 200°F.±1°. Green flashes at and below 199, red at and above 201. Now you have the choice of *several* modes of control:

(a) Open wide the valve when the green light flashes; shut it dead when the red light flashes; and when the white light flashes you do nothing—you just *wait* for the *other* light, which is bound to appear sooner or later. See 8(a).

(b) Open wide the valve when the green light flashes; shut it dead when the red light flashes; and—while the white light flashes—you hold the lever at *one* definite intermediate point, which may or may not be correct.

(c) Normally—that is, on white—you hold at one mid-position; when red flashes you quickly shut down all the way; when green flashes you quickly open wide; but when white flashes you slowly travel your hand to mid-position and then hold.

(d) The opposite of (c), that is to say when red flashes you slowly move from mid-point toward closed; when green flashes you slowly move from mid-point toward open; and as soon as white resumes you quickly bring the lever to mid-point.

(e) Like 8(b) but you *stop* on white, wherever your hand happens to be. A very good mode of control! Far from ideal but it has excellent points: When red flashes you move lever downward with a definite rate of motion, stopping it *wherever it is* as soon as white flashes. Very likely the supply is now insufficient, so green will flash and you will immediately start opening, again stopping at a new point as soon as white again flashes. At this new point the supply will probably be slightly excessive for the normal demand, and red will flash sooner or later. The great advantage of this mode is that a change in the demand can be met by a change in the supply. Instead of obstinately returning to one mid-point on white, you try to accommodate the process.

(f) Like (b) above, but your "mid" point is actually the optimum valve opening—the one which a study of the process, the equipment and the valve has shown to preserve, under normal conditions, the equilibrium between the supply of heat units and their utilization and dissipation. Here we are assuming that the supply of heat is constant and that its utilization is likewise constant—which is never absolutely true and which is approximated only in processes of long duration in large pieces of equipment. If there were no variables you could quit your job!

(g) Similar to (f) but instead of immediately opening wide or closing down all the way you move the lever upward or downward at a definite rate. When red flashes, for example, you bear down slowly on the lever until white shows, when you *reverse* your motion as you did in (8b) but you *stop* at the optimum point and *hold* there until either color flashes. For many industrial processes this mode of control is *practically* as good as the ideal mode would be. (Here we must repeat that there can be no ideal mode, no man-made things so intelligent that it will adapt its behavior to any of the infinite combinations of time and quantity requirements, interpret all departures from normality and even forestall them by proper anticipatory action—"like stepping on the gas when you *see* a hill just ahead so that just before climbing you'll go a little above 40 but you won't run the chance of dropping to 30 as you would if you weren't watching the road.")

Did we say *several* modes? Here are six, and some involve rate of motion, which is generally adjustable. Having thus discovered the possibilities of modes of control with signal lights (which the reader has naturally understood to refer to all contact-making and-breaking devices) let us go back to the idea of watching a dial-indicating thermometer, which we assume to be super-sensitive and free from time lag. You are still working a lever-operated valve and your hand can travel ten inches up or down—that is to say, five inches either way from the exact mid-point which we now assume to be the optimum throttling position. The dial thermometer you are watching is graduated from 195 to 205°F. Your nervous system is perfect so that your reaction period is nil.

10. When conditions are disturbed so that the One Best temperature of 200° is altered, you act not only instantly but *proportionately*. Your mode of control will be somewhat as follows. Suppose that a load of cold material is entered into the apparatus, lowering the temperature to 198°; the motion of your hand exactly follows the travel of the pointer, so that when the pointer comes to rest at 198° your hand will be two inches up from mid-point—toward open—admitting more steam. As the pointer swing back to 200°, your hand swings back correspondingly to mid-point.

This mode is somewhat like the action ("action" is right) of the widely-used bellows type of self-operating temperature controllers, the valve stem being connected to the bellows and traveling correspondingly. To some extent this is also the mode of control of pilot valve controllers: the opening of the pilot valve varies exactly with the temperature. But is there a definite opening of the *controlled* valve for every opening of the *pilot* valve? Is it *possible*? Is it *desirable*? Read on . . .

11. You discover again—as you did with signal lights,—that there is no permanent mid-point—the optimum opening of the valve depending on the temperature of the steam, on its quality, on its pressure, on the temperature, mass and specific heat of the material, and on many other conditions and relations, so that it varies. Nevertheless, your hand exactly follows the pointer. You cannot continuously vary the optimum opening. You can only select, for the opening which corresponds to the 200° position of the pointer, one which comes as close as possible to the average optimum opening. In other words, if the optimum opening is six inches at night when the room temperature is low, and four inches in the early afternoon when there is less radiation from your apparatus, you can select five inches as the average optimum opening, and call it the correct valve opening for the process. In many cases this works satisfactorily.

12. You can conveniently adjust the correct opening as a result of your experience, and in fact, when you are "starting from cold" you deliberately disconnect yourself as an automatic controller: you open the valve wide, attend to various other matters, and when the pointer nears 200° you put yourself back on the job and set yourself for a five-inch opening.

13. In practice a *by-pass* is found useful for this purpose, and also to prevent the steam (or oil, gas or other fuel) being entirely shut off by the controller. The function of the controller is then to regulate the supply of heat within a narrower proportion of the combined supply. One disadvantage, however, is that if the by-pass is used for starting from cold and is then forgotten, the apparatus may overheat. In the case of a large furnace, overheating is often disastrous.

14. Up to now you have been opening and closing an ideal valve with effortless ease. We now give you a more difficult job—exerting strength against steam pressure and friction. To save words, we need not repeat the above cases with pilot lights and with following the pointer, but it must be mentioned that if the steam pressure varies, while your strength remains constant, you will not be able to follow the pointer accurately. (Extremely useful as are the bellows controllers, they are open to this objection, which is generally inconsequential but sometimes worth considering. Moreover, in operating ordinary globe valves, it is always important to make sure that the likelihood of incomplete closing is not objectionable. It should not be where a bellows controller is applicable, for the matter is simply disposed of by placing a hand valve on the same line, which is usual in practice. As to the pilot valve controllers, if the force of the pressure medium is opposed by the steam plus a spring, hourly variations in the steam supply affect the relative positions of the pilot valve and steam valve, because these springs are seldom adjusted. If on the other hand, the pilot valve operates a cylinder arrangement, the case is entirely different, and a greater flexibility is obtained, the mode being consequently different and requiring separate discussions which will be given in case 15.

15. An improvement over 9(e): You are able to accommodate not only the *rate* of motion but the power required to operate the valve. And you are watching a pointer—not a set of lights. As near the ideal mode as anyone may desire! (Actual installations capable of this mode run to hundreds of dollars but are used on large applications where thousands of dollars are soon saved.)

16. In some of the above modes of control, there was a definite rate of supply for every extent of departure of the pointer from the desired temperature. Having gained a lot of experience, you discover an important principle which immediately promotes you from the freshman class to the post-graduate. It is this: The position of the pointer *at any instant* is not a truthful indication of that *demand* which will most quickly restore normality. When conditions have been upset, the pointer swings *away* from the setting; when the corrective measure is being applied, the pointer is swinging *back* toward the one best temperature. Here we must leave off our steam heated application and take for example a normalizing furnace 75 feet long. It takes a large quantity of heat to maintain, say, 1680° while the tonnage of sheets is being conveyed through the furnace. The moment you stop feeding in the steel, the demand will be reduced to an insignificant proportion. The big burners can be turned down to mere pilot lights to maintain 1680° temperature of the furnace atmosphere. On the other hand, merely changing the gauge of the steel produces a smaller change in the demand. Now, even with a *constant* flow of steel through the furnace there *will* be slight variations of conditions resulting in slight temperature fluctuations, to minimize which is the function of a pyrometric controller. Assuming you are the pyrometric controller. How will you distinguish between large and small changes in demand? Obviously, by the difference in the rate of change of temperature—by the speed of the rise or fall. The time element here enters again—but not in the form of instrument lag or process lag. You therefore ask for a timing device. We offer you a choice of two principal classes: (1) The depressor bar mechanism of a millivoltmeter, or (2) the periodic measurement of temperature which characterizes the potentiometer. You are now able to govern the *extent* of your corrective action according to the order of the increment or decrement of the temperature in a given time interval. (Note that now the instrument plays a more important part in temperature control, but also that the importance of the mode of control obtainable with the controlling *mechanism* is still greater.)

17. Having learned to recognize both *demand* and *departure*, you now decide that a valve movement corresponding always and exactly to the pointer movement lacks the required "intelligence." You therefore establish for yourself a *double* mode: For *any* departure you will immediately exert a definite amount of muscular force. If it results in restoring the desired temperature, well and good! You return to normal position. But if it does not, you will exert a *greater* amount of force. (This is a rough explanation of "three-point" electric control.)

18. An instrument which embodies the time element in a convenient way is the recorder. If you are watching a recorder instead of an indicator or a set of signal lights you can form a much better estimate of changes in demand and of the consequent extent of the necessary corrective measures.

At this point, we may now assume that the reader's critical judgment has been sufficiently sharpened to appreciate the fine points of modern

control systems which have been brought out in 1929 and 1930; that he will not be bewildered by such terms as "trend," "anticipating," etc., etc. . . . and we may leave off, although there is much more to be said.

In discussions of various modes of control, certain expressions are often used. Their meanings have not yet been defined uniformly by various instrument manufacturers and in various industries, but the following definitions should prove helpful.

"Overshooting"—Effect of not stopping corrective action soon enough.

"Hunting"—Rhythmical opening and closing (whole or part) of a valve due to improper mode of control for application.

"The controller fights the valve"—What happens when the swing of the primary element is not adjusted to that of the heat supply valve, or vice versa. Example: pilot valve open at 210° (allowing pressure medium to exert full force—say 1000 lb.—to close supply valve) and closed at 190° (allowing full opening of supply valve), so that at 200° an intermediate force, say 500-lb., is applied on supply valve, BUT with a 500-lb. force on supply valve, supply is too small for demand and temperature will drop. Remedy in most cases: adjust the spring of the supply valve which opposes the pressure medium coming from the pilot valve; or else just reset the by-pass valve.

5. Locating the Primary Element

The location of the primary element is an all-important factor in determining the efficacy of automatic temperature control devices. Requirements vary with almost every different industrial application, so that a comprehensive set of rules cannot be drawn up. Nevertheless, a few general statements may be made, which apply to the majority of industrial installations:

1. The thermal system responds to the temperature of the bulb or thermocouple. Therefore, the primary element should be so located that *its* temperature will either be identical with that which it is desired to control or exactly so many degrees above or below it. In a glass tank, for example, the thermocouple may be located in the wall and its temperature will, therefore, be that of the wall material surrounding the junction—less than that of the molten glass—but the conductivity of the two or three inches of clay or mullite which separates it from the molten glass being a constant, and the changes of temperature taking place slowly, there is no objection.

2. Where rapid changes of temperature are possible, the bulb or thermocouple should have the least possible amount of protection, and this protection should have the highest possible conductivity. In the glass tank example just cited, the thermocouple temperature lags considerably behind that of the melt, but in comparison with the rate of heating or cooling of the glass, this lag is almost insignificant. On the other hand, in a very small gas-fired furnace where the heat storage capacity is low, the ideal is a bare thermocouple.

3. With relation to the controlled heating medium or "source," there are two extremes: If the primary element is close to it, this source or medium will be controlled with minimum lag but regardless of the temperature in other parts of the equipment; if it is at the point where changes in the heat supply take longest to show up the process lag will reach its maximum value—which may or may not be desirable. In an ordinary household refrigerator the controller bulb is generally placed close to the cooling coils where the opening of the door has the least effect, because if it were placed near the door the current consumption would be unnecessarily excessive. In continuous chemical processes where the temperature of a fluid passing from one apparatus to the next is the important factor, the *outlet* of the first apparatus is the proper location for the bulb.

4. An actual case: A recording and controlling pyrometer installation. The charts showed a fairly even line but the operating men complained of lack of uniformity in the steel. It was discovered that the thermocouple was heavily protected. A recording pyrometer was installed on the same furnace, with a bare couple next to the protected couple of the controller. This new instrument showed a very poor record—which was the actual condition. The protection of the controlling pyrometer bulb was then removed and the record was immediately smoothed out and the operating men expressed complete satisfaction.

5. Several pertinent points are brought out in Fig. 108, of which it may be asked, "What is wrong with this picture?" It is an example of an

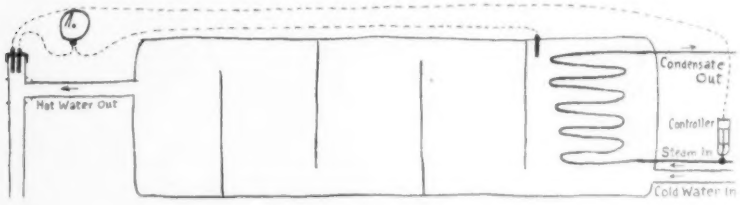


Fig. 108. "How not to do it."

installation where even the best made temperature controller could not possibly give satisfactory results. Assume that the temperature of the cold water is 70°; that the desired temperature of the hot water is 170°; that the normal demand is 500 lbs. of hot water per minute; that the maximum opening of the controlled valve admits 300 lbs. of saturated steam per minute (initial temperature 255°F.); that with normal demand it takes five minutes for the water to travel from the inlet to the outlet; that when the demand falls down to zero the temperature of the hot water in the outlet line starts dropping at the rate of 10° per minute so that after five minutes it is only 135°; and that the temperature controller is of the bellows type, set at 170°, with a working range and various adjustments which cause it to close the supply valve at 175° and open it wide at 165° *bulb* temperature. The reader will find it interesting to work out what the chart of the two-pen recording thermometer will look like when the demand is 500 lbs. of hot water per minute, when it is 250 lbs., and when it is 50 lbs. A hint: When the demand is nil, the temperature in the hot water line will in time drop down all the way to 70° or room temperature while steam will be generated in the right hand end of the heater.

6. Classes and Types of Elements

Owing to the great variety of hook-ups, as mentioned above, only the most important or interesting can be considered. There are no sharply-defined recognized classes and types. Manufacturers designate their products as they please. We find the designation "power element" applied to a primary element which merely actuates a relay. We also find the word thermostat applied not only to self-contained devices but to elaborate and almost fully-adjustable systems deserving of a better name. We find valve-operating mechanisms called "controllers" and "regulators" although they embody neither primary element nor relay. Even the expressions "direct-acting" and "reverse-acting" are used in exactly *opposite* senses by different manufacturers of almost identical products. In the face of such a situation the author, while refraining from starting a movement for uniform

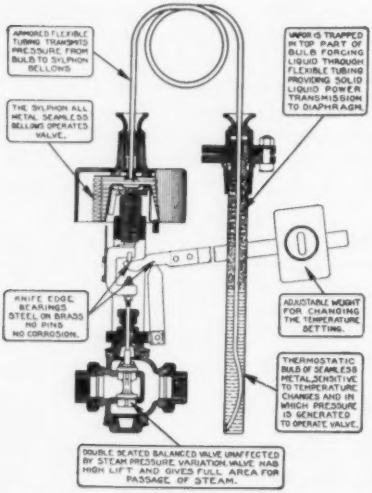

ARMORED FLEXIBLE TUBING TRANSMITS PRESSURE FROM BULB TO SYLPHON BELLOWS.
THE SYLPHON ALL METAL SEAMLESS BELLOWS OPERATES VALVE.
VAPOR IS TRAPPED IN TOP PART OF BULB FORCING LIQUID THROUGH FLEXIBLE TUBING PROVIDING SOLID LIQUID POWER TRANSMISSION TO DIAPHRAGM.
KNIFE EDGE BEARINGS STEEL ON BRASS NO PINS NO CORROSION.
ADJUSTABLE WEIGHT FOR CHANGING THE TEMPERATURE SETTING.
THERMOSTATIC BULB OF SEAMLESS METAL SENSITIVE TO TEMPERATURE CHANGES AND IN WHICH PRESSURE IS GENERATED TO OPERATE VALVE.
DOUBLE SEATED BALANCED VALVE UNAFFECTED BY STEAM PRESSURE VARIATION VALVE HAS HIGH LIFT AND GIVES FULL AREA FOR PASSAGE OF STEAM.

Fig. 109 (above.) Vapor-pressure thermal system ending in sylphon bellows actuating balanced supply valve. Adjustment effected by shifting weight. (*The Fulton Company.*)

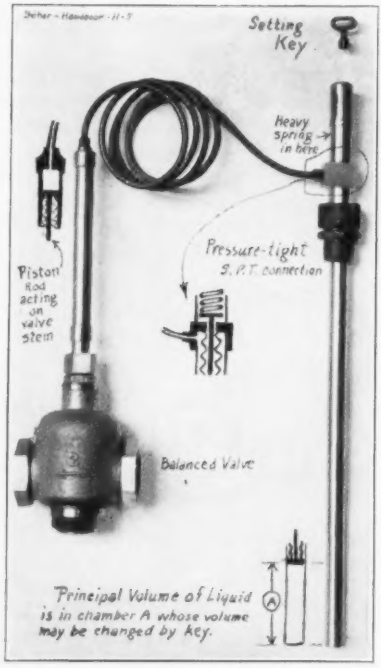

Setting Key
Heavy spring in here
Pressure-tight S. P. T. connection
Piston Rod acting on valve stem
Balanced Valve
Principal Volume of Liquid is in chamber A whose volume may be changed by key.
A

Fig. 110 (right). Liquid expansion primary element. Largest volume of liquid being at end of bulb, that portion is most responsive. While system is classified as "pressure-spring," it ends up in a piston which actuates the balanced valve. Pressure developed is opposed by non-adjustable spring under valve. (*Sarco Co.*)

TYPICAL INDUSTRIAL SELF-OPERATING TEMPERATURE CONTROLLERS

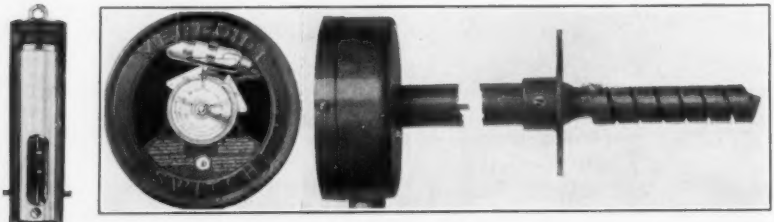


Fig. 111 (above). Bimetallic primary element in the form of a coil, actuating a mercury switch. (*The Mercoid Co.*)

Fig. 112 (Left). Modified Beckmann thermometer with platinum wires fused in capillary. Temperature setting adjustable by transferring part of mercury thread to reservoir. (*American Instrument Co.*)

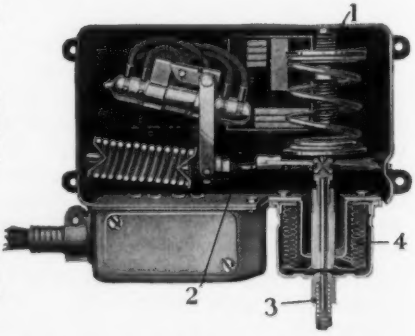


Fig. 113 (Right). Two-circuit type Mercoid control. 1—Temperature setting cap. 2—Differential adjusting screw. 3—Connection to remote bulb. 4—Bellows type pressure spring. (*American Radiator Co.*)

VARIOUS FORMS OF "ON AND OFF" THERMOSTATS

nomenclature, is forced for descriptive purposes to lay down certain definitions.

Primary Element—The part which is exposed to the temperature which it is desired to control.

Primary System or *Thermal System*—The primary element itself when it actuates a valve or relay, or the portion of a temperature control outfit which starts at the primary element and ends at the relay or at the supply valve itself when there is no relay.

Relay—A means whereby a feeble expenditure of power may govern the employment of a greater power.

Relay System—Self-explanatory.

Power System—That which operates the final element of a temperature control system. It embodies (or consists of) the *energized device*.

Final Element—The supply valve, damper, etc. Note that where temperature is controlled by regulating the flow of the heated liquid, and on other applications as well, it is not the supply valve which is ultimately operated by the temperature control system, but the flow-controlling valve or the damper. On an ordinary house-heating furnace or on an open-hearth furnace the *source* of heat is not controlled by the temperature controller, but only the draft.

(a) Thermal Systems

These may be tabulated as follows. The table covers only the broadest classification. For characteristics of thermal systems refer to Table I, page 161. Another purpose of this table is to refer the reader to illustrations of either thermal systems or contact, relay and pilot devices used in conjunction therewith. Note that where no figure number appears, it means that the combination is either impracticable or simply unusual.

Classes of Primary or Thermal Systems	No Relay	Classes of Relays		
	"Self-operating"	Compressed air up to 50 lb. or low-pressure hydraulic	Steam, gas or other controlled medium	Electrical
	Fig.	Fig.	Fig.	Fig.
1. Mercury-in-glass	.....	.....	.....	112
2. Pressure-spring:				
Combined bulb form	103	.....	.....	113
Distant bulb form	102, 109, 110	104, 123, 124, 125, 127	114	115
3. Solid expansion:				
Rigid stem form	101	126, 128	.....	116
Spring form	.....	.....	.....	111
4. Resistance 5. Thermoelectric 6. Radiation	.....	.....	.....	105, 106, 107, 129 to 136

1. *Mercury-in-Glass*—A common thermometer may be made to signal or to actuate a relay by fusing two platinum wires in the capillary. With the ordinary "non-adjustable" thermometer, the temperature setting can-

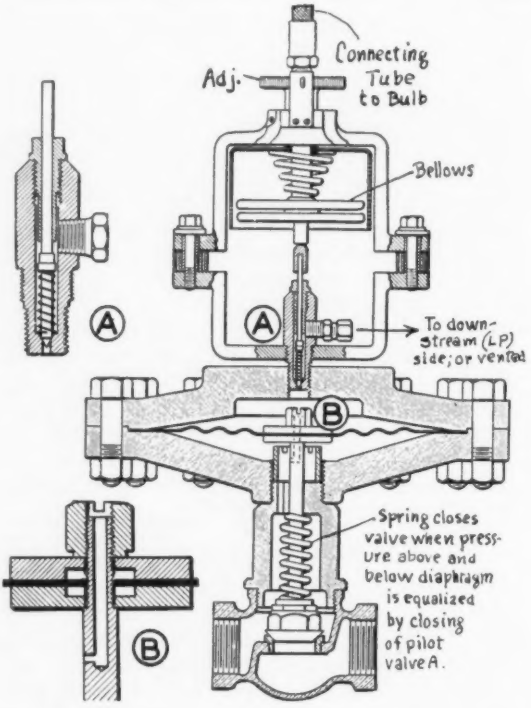


Fig. 114. Steam-operated temperature controller. Steam enters the valve body at the left and is always free to pass through the bonnet and through orifice B in the diaphragm, so that it always exerts pressure above as well as below the diaphragm. When pilot valve A is *closed*, the steam pressure is equalized above and below the diaphragm and no force opposes the mainspring, which then closes the valve. (Steam pressure helps keep the valve closed tight.) When the pilot valve is *wide open*, steam escapes through it more rapidly than it can pass through diaphragm orifice B and consequently the steam pressure below the diaphragm is greater than that above. The diaphragm is raised, and the steam valve is opened wide. At *intermediate openings* of the pilot valve, the steam valve will throttle. The opening and closing of the pilot valve is accomplished by the usual thermal system consisting of sensitive bulb, connecting tube and capsular spring. (*C. J. Tagliabue Mfg. Co.*)

not be modified. Nevertheless, we know of at least one such device which is adjustable even though the wires are fused immovably. The adjustment consists in drawing off any desired length of mercury thread from the capillary to a reservoir which is connected thereto—an operation which naturally requires some practice in order to obtain the desired setting. This class of mercurial thermometer is known as the Beckmann thermometer and was not mentioned under mercurial thermometers in part 2 of this chapter because the Beckmann thermometer is a laboratory instrument. Fig. 112 shows the appearance of an industrial type of Beckmann thermometer adapted for automatic temperature control.

2. *Pressure-Spring*—The characteristics have been gone into very thoroughly in part 1. See page 161 and also pages 168 to 176—especially the table on page 172.* The only additional comment needed in connection with temperature controllers is that while the bulbs and connecting tubes may be identical with those used in connection with dial-indicating and recording thermometers, the pressure-springs may be given different forms. A common form is a bellows in the self-operating controllers; another is the capsule or box diaphragm for actuating a relay. In practice it is found necessary to make the bulbs larger when the tube system ends in a power bellows. A bellows shaped bulb, filled with suitable liquid, may itself actuate a relay. Such is the principle employed in the device shown in Fig. 113. For that matter, the simplest "temperature controller" employing this principle is a radiator trap or air thermostat with a bellows which directly operates a valve.

*INSTRUMENTS, March, 1930.

3. *Solid Expansion*—Both the bi-metallic and the metal-and-refractory classes of primary elements are widely used for automatic temperature control. For indicating and recording instruments solid expansion elements cannot be utilized satisfactorily above 1000°F., but for automatic control where only one temperature is of importance they can be used above red heat, and manufacturers' catalogs actually give 2000°F as the upper limit for the rigid stem type. The "rod thermostat" has a long rigid stem which develops enough power to actuate a supply valve. When the thermal system merely actuates a relay, the stem may be made smaller and instead of a rigid stem, a bi-metallic spring may serve the same purpose.

4. *Electric Resistance*—Nothing to add to the previous discussions of this class of primary systems under indicating and recording thermometers. In temperature control, it ends up in a millivoltmeter or potentiometer and either of these instruments is modified for the purpose of effecting control, without affecting the thermal system.

5. *Thermoelectric*—Same remarks.

6. *Radiation*—Same remarks.

See below for descriptions of controlling millivoltmeters and potentiometers.

(b) Relays

The design of the relay is one of the factors which determines the mode of control of a temperature control system. Until 1928 this whole subject could have been summed up in the following general statement: *Fluid relays give throttling action; electric relays give on-and-off action.* We even find similar statements made in articles in industrial papers, and in papers read before engineering bodies, in 1929 and 1930. Developments which began soon after the war and which reached commercial forms in recent years have entirely changed this situation. The progress may be summed up in the one word, *adjustability.*

Inasmuch as the action of the relays must be considered in relation to the performance characteristics of the power systems which begin with such relays, mere descriptions of pilot valves, electric contacts, etc., would be of small service to the reader who is naturally more interested in what these devices can do than in how they are constructed. Nevertheless, the construction of various relays is shown in some of the illustrations, and the following discussion goes into some details.

1. *Pneumatic*—Compressed air has been used with remarkable success for more than a quarter of a century. Its overwhelming advantage is flexibility. There are three distinct relay principles whereby compressed air may be employed. (*a*) The "flap" or controlled leak principle, whereby a vent is introduced in the air line between the air supply and a diaphragm. Thus, if the vent is closed, the full force of the compressed air acts on the diaphragm; if the vent is wide open, the pressure on the diaphragm is negligible; and when the flap is in an intermediate position, the pressure is such as to give throttling action. The diaphragm may actuate a second relay, or operate a supply valve. (*b*) A vented pilot valve placed in the air line. When this valve is open, the entire air supply acts on the diaphragm; when it is closed, the supply is intercepted and then the diaphragm vents to atmosphere; in an intermediate position, part of the supply is vented and part acts on the diaphragm. The diaphragm is usually a power device operating the supply valve. The proper employment of this principle requires that the vented pilot valve be fully adjustable. (*c*) A pilot

controlling pressure above *and* below a diaphragm or piston. The feature of the application of this principle is that the supply is diverted into two controlled air lines so that the power may be exerted in one direction or the opposite direction, thus obviating the necessity for springs opposing the pressure on one side of a diaphragm. With proper design, construction, and above all with proper adjustment, the mode of control obtainable approaches perfection.

2. *Hydraulic*—Somewhat similar to pneumatic but characterized by less flexibility—water being incompressible. It must also be added that there is a great distinction between the use of city water and of hydraulic pressures which may run above 1000 lbs. per square inch. With a supply of city water, temperature controllers embodying an air relay valve may be used, provided only that they are designed for such alternative purposes. High hydraulic pressure may be used in *secondary* relay systems, the primary relay system merely actuating a second pilot device whereby the high pressure is utilized to perform operations beyond the power of compressed air or city water. Seldom used on ordinary temperature control applications. Cost of installation is much greater than those with single air relays. Advantage is *exactness* of control. Successfully used on large and important applications.

3. *Steam, Gas, etc.*—Some temperature controllers are designed with pilot valves utilizing the pressure of the controlled medium in order to obviate the necessity for auxiliary power such as compressed air, water or electricity. For the control of steam supply, steam operated controllers such as shown in Fig. 114, may be used. For the control of gas or oil burners, the primary element may actuate a relay in the form of a pilot valve through which the gas, air, oil, etc., is governed on its way to a diaphragm.

4. *Electric*—These may be divided into two broad classes: Open contacts and sealed mercury switches. All electric relays are on-and-off in their *initial* action, but remember that this is only the start of the electric power system. Numerous newly-developed electric power systems produce

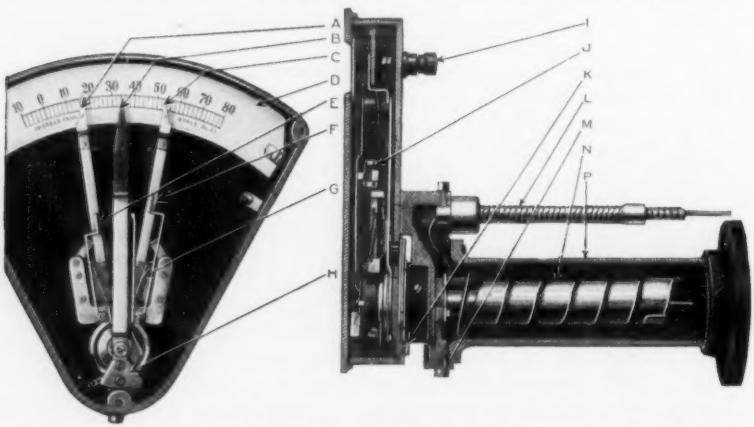


Fig. 115. Pressure-spring primary system, electric contact relay system, indicating form with visible adjustable high and low contacts. A—Low adjustable contact arm. B—Indicating pointer. C—High adjustable contact arm. D—Scale plate. E—Low adjustable contact. F—High adjustable contact. G—Contact spring. H—Pointer counterweight. I—Binding posts. J—Indicating pointer contact. K—Button for adjusting contact arms from outside of case. L—Armored capillary tubing extending to bulb. M—Zero adjustor. N—Pressure spring. P—Pressure spring housing, also forming bracket to fasten instrument to wall. (*The Bristol Company.*)

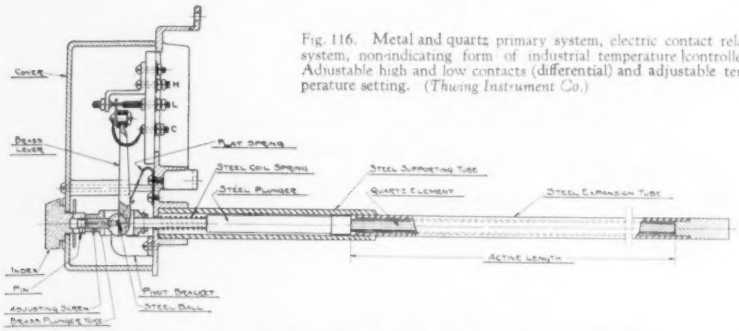


Fig. 116. Metal and quartz primary system, electric contact relay system, non-indicating form of industrial temperature controller. Adjustable high and low contacts (differential) and adjustable temperature setting. (*Thwing Instrument Co.*)

modes of control equivalent in their flexibility to pneumatic operated devices. Details below under various pyrometric controllers. Recent developments in electrical engineering are now being utilized in temperature control applications.

(c) Energized Devices

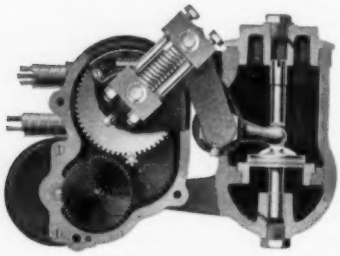
This heading covers the elements that perform the actual work of *operating* (not "actuating") the supply valves or other final elements. They may also be called valve-operating mechanisms. Some have specific names such as "diaphragm-motors." Some are called "controllers" by their manufacturers, no doubt following electrical engineering practice, but this is somewhat confusing. "Motors" would be a correctly descriptive name but some of these devices consist of electric motors together with gear trains, etc. "Power devices" has been suggested in view of the fact that such devices imply the application of auxiliary power. "Operating devices" may also do but for the fact that as parts of control systems they are operated devices. At any rate all these energized devices deserve consideration instead of being taken for granted as they often are.

In self-operating controllers there is no separate energized device—the thermal system, whatever its class or type, operates the supply valve. Therefore, since energized devices are used only in connection with auxiliary power they can logically be classified according to the form of such power. Thus with pneumatic power we have the familiar diaphragm motor; with hydraulic power we have cylinder-and-piston devices; with electric power we have two principal types according to whether solenoids or common motors are used. As in the case of relays, descriptions of energized devices by themselves without regard to what precedes them, would be getting away too far from the purpose of a handbook on instruments. Nevertheless, some modern developments in these devices are described in detail below as part of the discussions of various standardized industrial temperature control systems, and in a special section at the end of this chapter.*

(d) Valves, Dampers,etc.

Here again, we are getting so far away from the main subject of instruments that it is necessary to refer the reader to mechanical engineering handbooks, valve manufacturers' catalogs, etc. Nevertheless, the importance of proper valve selection (which often may be the first step in the choice of a temperature control system) has dictated the inclusion of several illustrations of special valves designed for use with control instruments.

*This section will appear in the next issue of INSTRUMENTS—Ed.



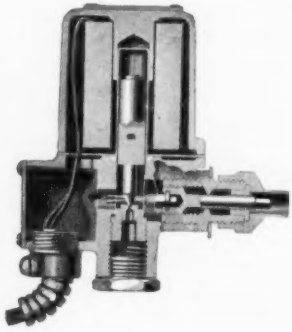


Fig. 117 (above). Motor valve for use with instruments equipped with two-circuit mercury switch (three-wire circuit). Operation takes eight to ten seconds. Fig. 118 (right). Solenoid valve for oil, gas, water or air. Current failure causes valve to close. Adjustments on main flow and by-pass. (*American Radiator Co.*)

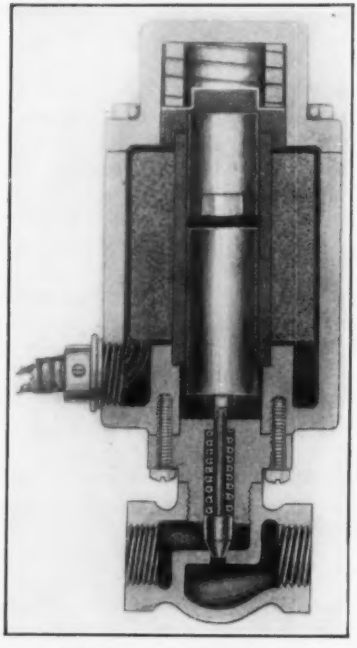


Fig. 119. Solenoid-operated packless needle valve for oil, air, water or brine. Controlled fluid can flow into plunger chamber without causing injury. Valve opens with magnet energized. Current failure causes closing. (*Electric Valve Mfg. Co.*)

Fig. 120. The familiar diaphragm-motor valve used in connection with fluid-relay ("throttling") controllers. Hundreds of types and models are used on industrial applications. This form closes in the event of failure of air pressure. (*The Foxboro Co.*)

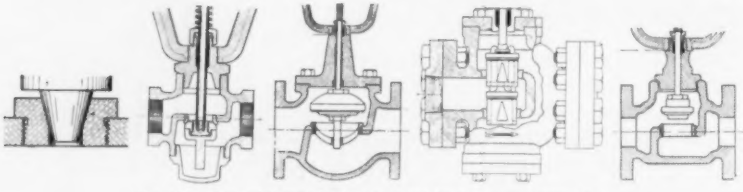


Fig. 121. Typical forms of valves operated by diaphragm-motor tops.

7. Typical Industrial Temperature Controllers

In practice the engineer can seldom *separately* select the one best class, type and make of each of the several elements of a temperature control system. He is more or less forced to "take what he can get." Fortunately, many years of experience by numerous manufacturers have resulted in more or less standardized satisfactory combinations of elements. An air-operated controller, for example, is now understood to mean an outfit comprising a pressure-spring thermal system, a pilot air valve enclosed in a handsome panel-board type case with setting dial, and a diaphragm-motor factory-assembled to the supply valve—the entire outfit being furnished by one manufacturer complete, including even air filters, air strainers, air supply gage, controlled air gage and other appurtenances. The same manufacturer can also furnish an air compressor of the proper capacity and with belt-, steam- or any motor-drive desired. In the following pages, therefore, we shall recognize the actual conditions which govern the actual selection of control systems, and describe several "temperature controllers" ranging from the simplest self-contained self-operating non-indicating devices to some of the most elaborate—ranging also from well-known devices that have been on the market for a number of years to new industrial developments which are here described for the first time.

(a) Self-Operating Controllers

These may be self-contained, as is the one shown in Fig. 101, or with flexible armored connecting tube between bulb and bellows, as in Figs. 109 and 110. We use the term "bellows" which is the usual form of the element which acts on the valve stem and of which the Sylphon is the most famous example; but the actuating element may be a piston, as shown in the illustration of the Sarco. Self-operating controllers are all non-indicating—meaning that the *temperature* is not indicated; but several forms are made up with a scale showing the extent of the bellows expansion, which primarily serves as a tell-tale of the valve operation, and may also serve as a rough "thermometer." All are made adjustable for temperature setting, but some are much more easy to set than others. Some have setting dials, most of which simply read "warmer" and "colder." Some dials are calibrated in degrees of temperature but the variability of the force which opposes the expansion precludes a degree of accuracy anywhere near that of a plain indicating instrument. As a rule the parts are neither separable nor interchangeable, except, of course, for the valve parts; but a striking exception is furnished by one model of the Sylphon controllers which embodies a removable transmitting system consisting of two Sylphon bellows joined by a flexible tube. This model thus consists of three easily separable parts. Self-operating controllers are simple, inexpensive, easily installed and satisfactorily serviceable when called upon to do a job within their power. This power is naturally limited, and in many cases fails to close the valve completely against the steam pressure, thus allowing a small leakage of steam. Moreover, since the bellows operates directly against the valve stem it follows that the movement of the valve stem is proportional to the temperature change at the bulb. For example, a twenty-degree temperature change might be necessary before the valve would move from open to shut. Self-operating controllers are never made up with large valves or even with medium-sized valves operating against high steam pressures. (For valve size limits please refer to manufacturers' catalogs.)

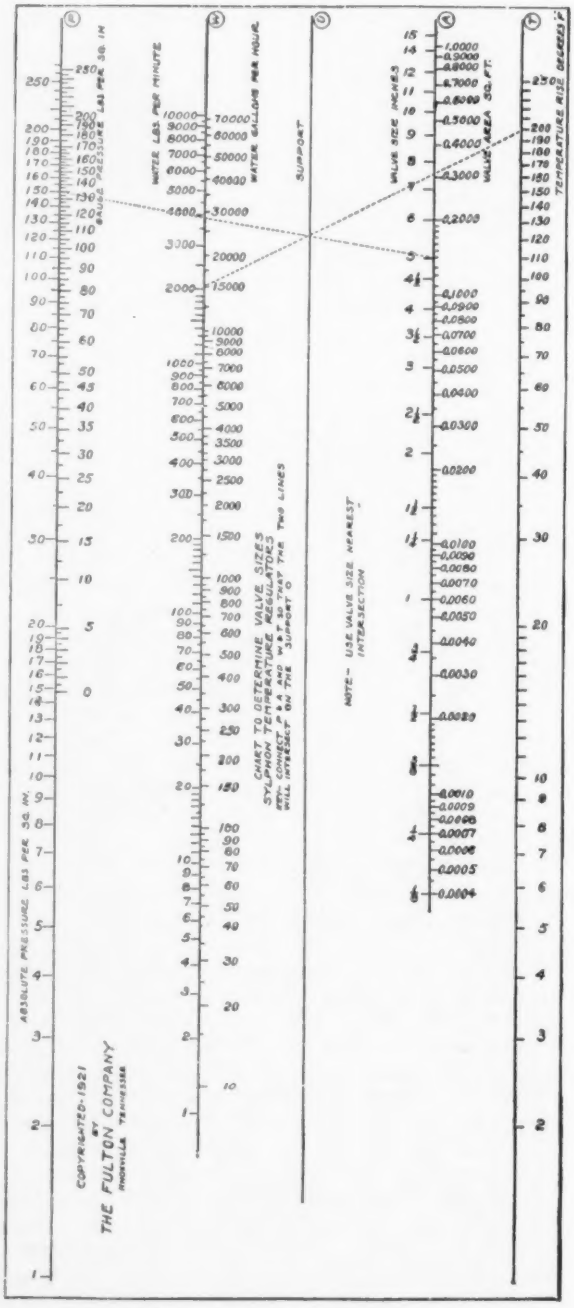

ABSOLUTE PRESSURE LBS PER SQ. IN.
GAUGE PRESSURE LBS PER SQ. IN.
WATER LBS PER MINUTE
WATER GALLONS PER HOUR
SUPPORT
VALVE SIZE INCHES
VALVE AREA SQ. FT.
TEMPERATURE RISE DEGREES F.
COPYRIGHTED 1921 BY THE FULTON COMPANY KNOXVILLA TENNESSEE
CHART TO DETERMINE VALVE SIZES STYLE "T" SELF-OPERATING TYPE
NOTE- USE VALVE SIZE NEAREST INTERSECTION

Fig. 122. Chart for calculating sizes of self-operating temperature controllers. Though applicable only to Sylphon controllers it is of general usefulness. It shows four quantities which are usually considered in calculating temperature controller sizes, namely:

P—Steam Pressure (lbs per sq. inch).

A—Valve Size (area in sq. feet).

W—Quantity water heated (pounds per minute or gallons per hour).

T—Temperature rise of water (Degrees F.)

When any three of these quantities are known the fourth may be calculated, and they have been plotted graphically in this chart which makes the problem simple of solution. Five vertical parallel lines of which four are indicated by the letters above and marked thereon have all the values ordinarily used in temperature control problems. The fifth parallel line marked "O" is known as the "Support" and is used only as an auxiliary line. For instance, lines connecting "T & W," and "P & A," must intersect "Support" "O" at the same point to get a correct solution, as shown by the dotted lines on chart.

Example:

Suppose 15000 gallons of water per hour are to be heated from 40° F. to 240° F. The steam pressure is 135 pounds per square inch gauge. Required, the size controller necessary.

The temperature rise is 240—40 = 200° F.

With a straight edge connect 15000 gals. on "W" with 200 deg. F. on "T." Note the point where this line intersects the "Support," "O," connect with 135 pounds on "P," and prolong until it intersects "A," which gives the required valve size, 5 inches. Use the valve size nearest the intersection at line "A."

A value for any one quantity may be found when the other three are known. For instance, when the steam pressure, valve size and quantity of water are known, the temperature rise may be checked. Where a long run of pipe is necessary to bring steam to the controller, the pipe should be one size larger and reduced at the controller.

(b) Thermostats, Contactors and Electric Contact Controllers

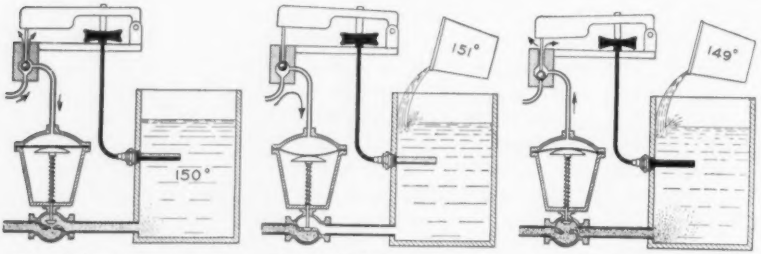
Knowing the hopelessness of standardizing the nomenclature of these devices and instruments, the author will merely describe some of them.

Some devices called thermostats are as described under the previous heading, and regardless of their designation, are in fact self-operating controllers. The application seems to make some difference. For example in a house, a pressure element responding to room temperature and operating the damper in the basement is called a thermostat. The *form* also makes a difference: The thermal system may for example actuate electric contacts through which a feeble current passes, this current in turn actuating relays which operate a valve or damper. In its simple forms such an instrument is a contactor. Now take the same principle but glorify it, so to speak, by making the instrument indicating and adjustable, and make it *look* like an instrument, and we now have what must be called an electric contact type automatic temperature controller. Such instruments are illustrated in Figs. 115 and 116. The principle may be the same as that of the cheapest thermostat or contactor, but the accurate indication of temperature, the convenience of setting both high and low contacts and the exactness of such setting which may be obtained, place these instruments in an entirely different class. The mode of control is on-and-off, the same as in the cheaper devices, but results are incomparably better. And when a floating type of motor-driven valve-operating device is used, the on-and-off impulses of the instrument are transformed to a flexible mode.

A wide variety of control devices produce a snap action in the primary element, whereby a switch is opened and closed. In probably the majority of such devices the familiar Mercoid switch is used. Here again the form of the device, its workmanship, the ease of setting and adjustments, etc., determine whether it is an ordinary thermostat or an industrial automatic temperature controller.

(c) Throttling Controllers

This heading is purposely adopted to distinguish controllers embodying *fluid relay systems*, pneumatic or hydraulic. The great majority are the familiar air-operated controllers—up to very recently the most highly perfected of all temperature control instruments. (And the challenge of the last twelve months' developments in pyrometric control is being met by a corresponding modernization of air-operated controllers. Only the most highly perfected of the electrical systems can equal the throttling mode of control obtainable with properly adjusted industrial pneumatic and hydraulic relays and valve-operating devices.) The word throttling conveys the idea and it applies to *two* distinct elements of the outfit: the controller and the controlled valve. The usual forms of throttling controllers have only one significant limitation: For every degree of temperature at the bulb, there is a definite opening of the pilot valve, and this relation is not changed automatically with changes in B. t. u. demand, but can only be changed manually. This imperfection of mode is not objectionable on the majority of industrial applications: on any adequately insulated equipment which has an adequate heat capacity, with a fairly steady steam or fuel-mixture pressure, the desired temperature may be maintained very closely. We know of an application where it is maintained within one-tenth of one percent of the controller range: the chart of the recording thermometer shows a line so smooth that deviations cannot be seen with the naked eye. The recorder is separate from the air-operated controller



The controller having been ordered for a setting point of 150°, the liquid in the bulb has been selected for that particular temperature and is now *partly* vaporized so that the capsular spring is expanded to an extent which causes the air valve ball to be held at an *intermediate* position. The controlled air line contains air at a pressure between 0 and 15 pounds—the 15 pound supply being throttled. Some air is allowed to escape through the discharge port around the valve pin; and the diaphragm-motor, actuated by an intermediate air pressure, *throttles* the steam valve just enough to maintain the One Best Temperature.

Normal conditions have been upset by the introduction of an exceptional quantity of heat. The liquid in the bulb is almost all vaporized and the capsular spring is consequently under a greater expansion. The air valve ball, acted upon by air alone, is held against the outlet port, shutting off all escape of air, opening wide the inlet port, and allowing the full supply to pass through. The controlled air line carries the full 15 pounds of air pressure to the diaphragm-motor, and the force thus exerted closes tight the steam valve. The steam supply being shut off, the tendency of the apparatus to overheat is immediately checked.

Again we suppose that normal conditions have been upset—this time by the introduction of a large quantity of substance at a lower temperature. The bulb is full of liquid and there is little or no vapor. There is little or no pressure inside the spring, the lever is all the way down, the air valve ball is held tight against the air inlet and compressed air is not allowed to pass. The air vent around the pin is open and all air pressure on the diaphragm top is relieved. The steam valve is held wide open by the spring and the steam pressure, so that the apparatus is allowed to heat up until the proper temperature is reached.

Fig. 123. Operation of vapor-pressure air-operated direct-acting temperature controller and direct-acting diaphragm-motor valve. Movements of capsular spring responding to changes of temperature at bulb purposely exaggerated. (*C. J. Tagliabue Mfg. Co.*)

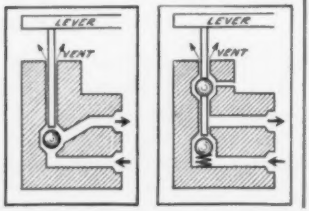
Air Valves

DIRECT-ACTING

Allows compressed air to flow to the diaphragm-motor when the transmitting lever moves away from the pin. May be embodied in all types of controllers.

REVERSE-ACTING

Allows compressed air to flow to the diaphragm-motor when the transmitting lever bears against the pin. (Is not embodied in mercury system temperature controllers.)



Diaphragm-Motor Valves

DIRECT-ACTING

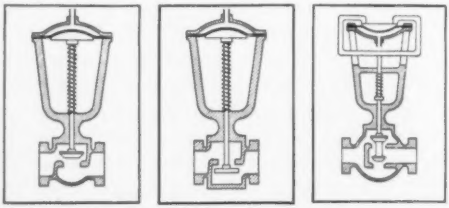
Closes on admission of compressed air to diaphragm top. When air is released, valve opens, as steam pressure is under the disc, and spring assists in opening.

REVERSE-ACTING

Opens on admission of air to top. When air is released, disc rises up against seat and closes valve. Spring assists in closing. When air fails, valve closes—a safety feature.

WITH REVERSE-ACTING TOPS

The air is below the diaphragm, and the saucer is located above it. Admission of compressed air *opens* the valve. Should air fail, valve will close.



Characteristics of Combinations

Application	Type of Controller	Type of DMV	When Temperature or Pressure		Forms of DMV's	Valve Size Limit
			Rises Above Setting Point	Falls Below Setting Point		
Heating (or Pressure Reduction)	Direct Acting	Direct Acting	DMV Closes Throttling Action	DMV Opens Throttling Action	Single and Double Seated	12"
	Reverse Acting	Reverse Acting	DMV Closes Throttling Action*	DMV Opens Throttling Action*	Single and Double Seated	12"
	Reverse Acting	With Reverse Acting Top	DMV Closes Throttling Action	DMV Opens Throttling Action	Double Seated Only	4"
Cooling (or Excess Pressure Relief)	Reverse Acting	Direct Acting	DMV Opens Throttling Action	DMV Closes Throttling Action	Single and Double Seated	12"
	Direct Acting	Reverse Acting	DMV Opens Throttling Action*	DMV Closes Throttling Action*	Single and Double Seated	12"
	Direct Acting	With Reverse Acting Top	DMV Opens Throttling Action	DMV Closes Throttling Action	Double Seated Only	4"

(*) Except single-seated reverse-acting valves over 2" which will not throttle.
By double-seated valve is meant a balanced valve. By single-seated valve is meant a globe valve type not balanced or not gate type. Single-seated balanced valves are available but of special construction.

Fig. 124. Action of types of pilot air valves and of diaphragm-motor valves and the six possibilities obtainable. (*C. J. Tagliabue Mfg. Co.*)

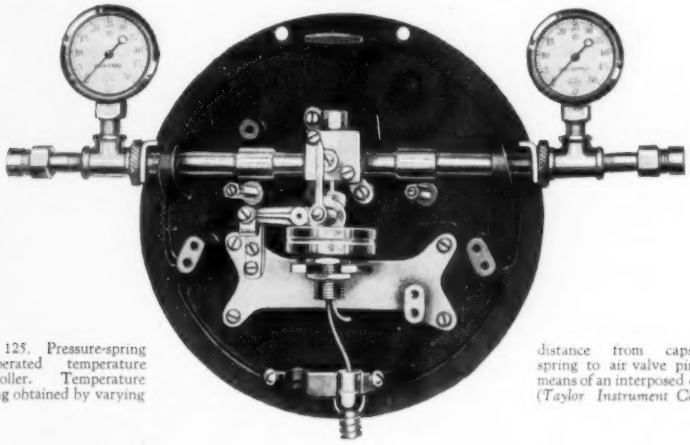


Fig. 125. Pressure-spring air-operated temperature controller. Temperature setting obtained by varying distance from capsular spring to air valve pin by means of an interposed cam. (*Taylor Instrument Cos.*)

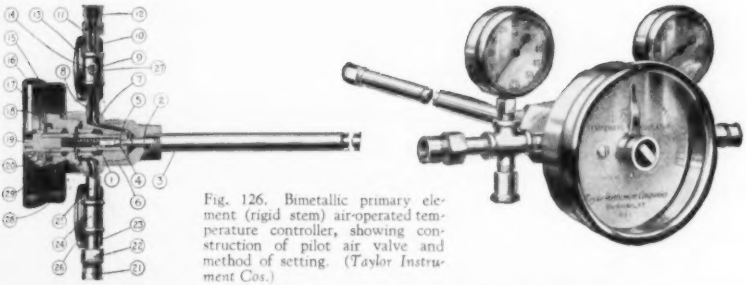


Fig. 126. Bimetallic primary element (rigid stem) air-operated temperature controller, showing construction of pilot air valve and method of setting. (*Taylor Instrument Cos.*)

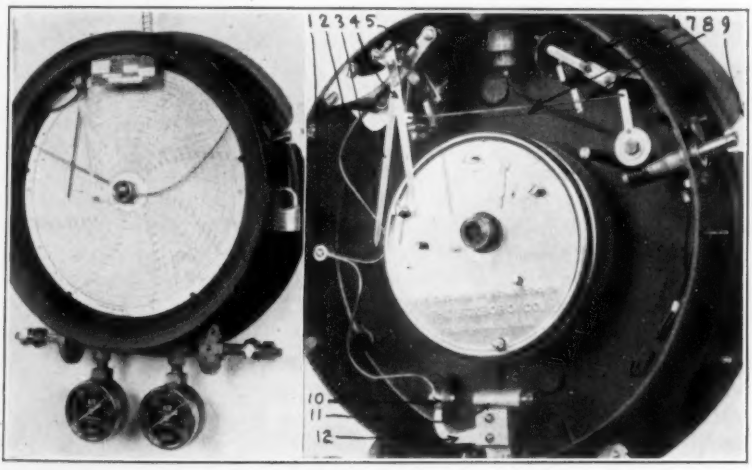


Fig. 127. Air-operated recorder-controller. Flapper method of air control. Index arm 3 is set at desired temperature by turning key 9. Attached to index arm is a small air nozzle from which a very small amount of air is continually escaping. Likewise to pen arm 4 (actuated by spring 6 through rod 7) is attached a small flapper valve. When control point is reached, pen arm is directly over index arm and flapper valve closes the air nozzle. This causes back pressure which operates the diaphragm 10 of control head 12. In the control head is a relay valve 11 which regulates air pressure change on the diaphragm of the controlled valve (*The Foxboro Co.*)

and its bulb is protected only by a fairly thin-walled Monel metal well, so that a fictitiously smooth record is out of the question.

In connection with the use of the well-known forms of throttling controllers (the air-operated instruments) several points deserve to be stressed:

First of all, the greatest help to the attainment of the best possible mode of control is the little pressure gage on the controlled air line which runs from the instrument to the diaphragm-motor valve. Watch this gage together with the indicating thermometer (which may be a separate instru-

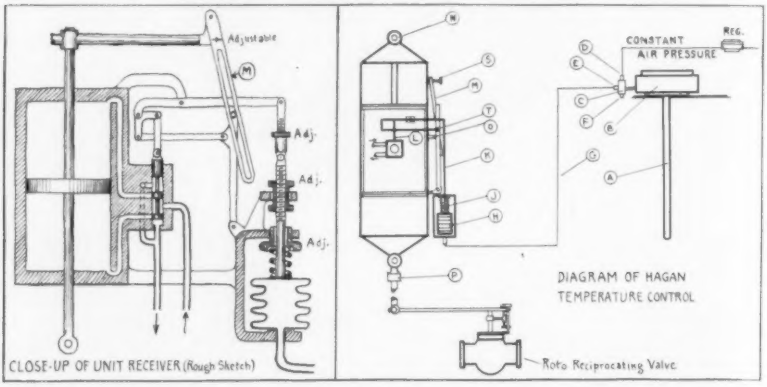


Fig 128

ment or may be embodied in the controller) and you will be able to know just *how* the controller throttles. Watch it in connection with the action of the diaphragm-motor valve, and you will know just how the valve throttles.

In specifying an air-operated control outfit, it is well to determine what should happen in the event of air failure. Should the diaphragm-motor valve open wide or close tight? Either effect is possible and one of the two should be selected.

This brings up the matter of direct and reverse action. (a) The controller may either increase or decrease the flow of air to the diaphragm-motor when the temperature rises. (b) The controlled valve may either open wider or close more when the air pressure to its diaphragm top increases. Moreover, the air may be introduced either above or below a diaphragm which operates a direct-acting controlled valve.

Thus with two types of air valves and three types of diaphragm-motor valves, six combinations are possible. See Fig. 124.

The controlling instrument itself may be non-indicating, indicating, or recording, as well as controlling. The non-indicating form may or may not have a setting dial calibrated in degrees of temperature.

One controlling instrument embodying one thermal system (bulb, tube and spring) can embody not one but two pilot valves. This type, the duplex, has three important applications in process work:

(a) For control of two sources of heat supply (with excess diverted)—When there is more exhaust steam available than needed, the excess amount of exhaust is diverted through one diaphragm-motor valve (to a feed water heater, atmosphere or elsewhere) and at such times the DMV on the steam line remains closed. When, however, there is not enough exhaust steam to keep up the temperature desired, the first DMV closes so that no exhaust

steam is diverted and a second DMV opens sufficiently to admit the additional amount of live steam required to meet the deficiency.

(b) For control of two sources of heat supply (with excess throttled)—When there is more exhaust steam available than needed a large DMV on the exhaust steam supply line admits only the required amount to the apparatus, and at such times a smaller DMV on the live steam line remains closed; when, however, there is not enough exhaust steam to keep up the temperature desired the large DMV is wide open so that all the exhaust is utilized, and the small DMV opens sufficiently to admit the additional amount of live steam required to meet the deficiency.

(c) For control of both a source of heat and a cooling medium—Of interest in chemists concerned with exothermic processes. When the temperature is initially brought up the DMV on the heating medium line is wide open until the desired temperature is reached, after which this valve throttles to meet the steam demands until sufficient auto-generation of heat causes this valve to close dead shut; the other DMV (on the cooling medium line) then admits cooling water and throttles the supply as needed to keep the temperature at the desired point until such auto-generation may require no more counteraction, after which it closes dead shut, and the first DMV again takes care of the steam supply.

Conversely, one diaphragm-motor valve may be operated by two compressed-air lines. Usual case: one air line from a temperature controller throttling the valve; the second from a timing control or a safety device, snapping it shut at a pre-determined time or in an emergency.

Engineers being familiar with the principle of fluid-relay controllers, construction details of the most widely used makes need not be dwelt upon beyond the various illustrations accompanying this text. One recently developed system however, will now be briefly described separately. It is selected for this purpose because, although its manufacturer is not an instrument company, its combination of massive construction with sensitivity affords an interesting example of what is being achieved in the way of temperature control equipment providing adjustable mode:

In the system of temperature control manufactured by the Hagan Corporation, pneumatic, or a combination of pneumatic and hydraulic equipment is used throughout. The primary element is mechanical. The relay is pneumatic, and the power device may be either pneumatic or hydraulic. It is possible to secure incremental reciprocating motion of the crosshead of the power cylinder which regulates the flow of the medium being controlled. This means that, depending on the adjustment of the various devices in the chain, it is possible to obtain at the end of the chain, i. e., the regulating valve, a small or large movement of the valve orifice, together with a self-adjusting normal valve opening.

A diagram of the system is shown in Fig. 128. It starts with a bi-metallic primary element A whose motion is transmitted through linkage in head B to *escapement* valve C upon which is impressed a constant pressure of compressed air at inlet D. As valve C is actuated, it either exhausts air at F from the system or admits more at E to increase the pressure in controlled air line G. Thus valve C holds back air, lets it pass or lets it escape in exactly the same manner as the pilot air valve described under Fig. 123. It is called the escapement valve because the real pilot valve of the power device is further along in the system. Moreover, its travel is adjustable in that a given temperature change at sensitive element A may alter the pressure in line G throughout the full range from zero to maximum or it may alter it over only a portion of this pressure range.

The power device, operating the heating medium supply valve, is termed a pressure Impulse Receiving Regulator. It receives the pressure impulse at metal bellows H. The expansion of this bellows is opposed by a spring J, the compression of which is adjustable. The range of impulse pressure required to expand the bellows from zero to its full working length is usually about 25 lbs. per sq. in. The bellows assumes a definite expansion for every pressure to which it is subjected. For every intermediate temperature deviation between zero and adjustable maximum departure there is, therefore, a corresponding *adjustable* bellows expansion.

Movements of bellows H are transmitted through link K to pilot valve stem L, admitting motive power fluid, air, oil or water supply to either side of the piston within the power cylinder. Flexibility in the power device is obtained through adjustable compensating bar M pivoted (in one form as shown in diagram) near its mid point to traveling side bar at O. The angularity of compensating bar M is thus adjustable by motion at its upper end by thumbscrew S. Sliding in guides at T is a link which reverses the motion of the pilot valve stem given in by bellows H. This affords the degree of compensation desired of the power cylinder crosshead. It is possible by having compensator bar M parallel to the side rods to eliminate compensation entirely, and for a slight movement of bellows H or link K to cause regulator crosshead to take a full stroke. By adjustment, the crosshead can be made to

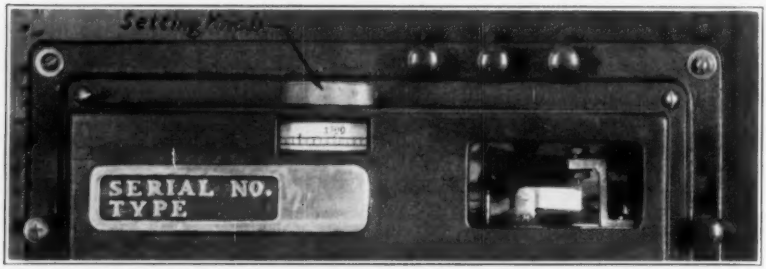


Fig. 129. Upper portion of controlling millivoltmeter (thermocouple, resistance thermometer or radiation receiver as primary element). A distinctive feature is that by means of the setting knob, the visble scale is rotated around the stationary instrument, thereby setting for the desired temperature and at the same time opposing the tension of control springs for such temperature. This spring tension is a mechanical equivalent of the "opposing emf" of the potentiometer circuit. The manufacturer states that "in fact this controller uses the null method." (*Thwing Instrument Co.*)

take a full stroke for maximum working stroke of bellows H, or if desired, a full stroke of bellows H can cause regulator crosshead to make only a partial stroke. Thus complete adjustment is secured and incremental movement is always obtained.

A "Roto Reciprocating" valve is designed for use with this receiving regulator. The lever of this valve has the same stroke as the regulator so that it may take advantage of all positive movements of the latter, which may compare to relatively small temperature changes and yet have the valve orifice opening altered only a proportionally small amount. The roto reciprocating valve is also adjustable. Its minimum opening may be made zero or otherwise, and then its maximum opening may be adjusted without interfering with the minimum. The minimum may be adjusted without altering the maximum.

The entire system is thus purely mechanical. It is designed for temperature control applications up to a maximum of about 2000°F, where positive incremental action is desired.

(d) Controlling Millivoltmeters

Different models of indicating and recording millivoltmeters have been illustrated in parts 3 and 4 of this chapter. With reference to control they all afford the same starting point—a *pointer* which deflects with practically no mechanical power and therefore cannot do any mechanical work. From this same starting point several industrial controllers take their initial impulse and relay it to valve-operating devices which range from solenoids and fractional horse-power motors to large reversible-motor and two-motor machines. The control mechanism proper generally starts with a means for periodically immobilizing the pointer. In the case of recording millivoltmeters this usually is the depression mechanism which presses down the pointer to make the mark on the chart. In the case of an indicator a separate mechanism, electrically driven, is provided for this purpose. Thus, with the pointer momentarily clamped, contacts can be made without the possibility of impairing the accuracy of the thermal system. The familiar high and low contact arrangements which were brought out before the World War still survive and render even better service because they are used in connection with improved energized devices.

It is precisely because of the recent developments in energized devices that controlling millivoltmeters have themselves been developed to send the proper impulses to the motor-driven valve-operating machines. Several names have been coined to describe the modes of control obtainable with such instruments, and to characterize the instruments themselves. The principal development may be summed up in the self-explanatory designation, "three-point" controllers. Such controllers can give any combination of three operations to cover the entire range of applications which cannot be handled by a straight on and off controller. This mode of control is rendered more flexible to give either continuous or intermittent operation. The broadest application is to gas furnaces where it is often necessary to maintain

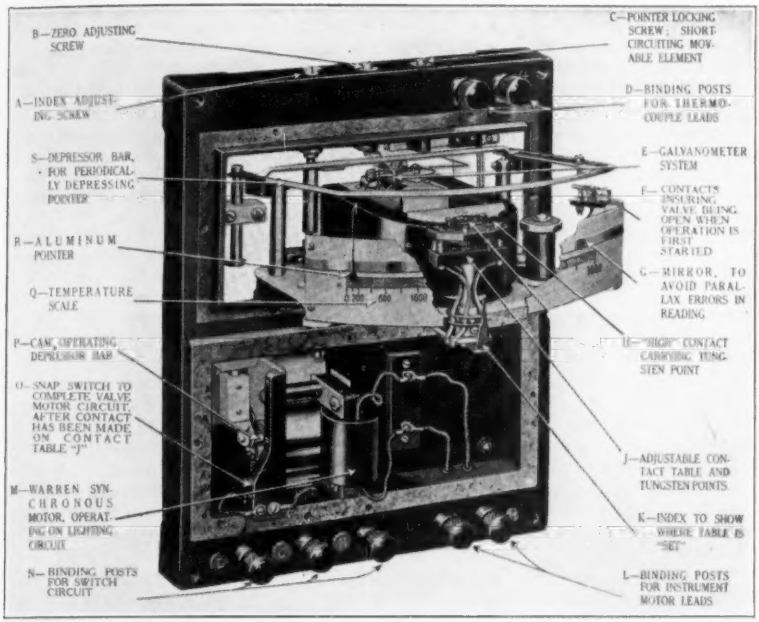

B—ZERO ADJUSTING SCREW
A—INDEX ADJUSTING SCREW
S—DEPRESSOR BAR, FOR PERIODICALLY DEPRESSING POINTER
R—ALUMINUM POINTER
Q—TEMPERATURE SCALE
P—CAM, OPERATING DEPRESSOR BAR
O—SNAP SWITCH TO COMPLETE VALVE MOTOR CIRCUIT, AFTER CONTACT HAS BEEN MADE ON CONTACT TABLE "J"
M—WARREN SYNCHRONOUS MOTOR, OPERATING ON LIGHTING CIRCUIT
N—BINDING POSTS FOR SWITCH CIRCUIT
C—POINTER LOCKING SCREW; SHORT-CIRCUITING MOVABLE ELEMENT
D—BINDING POSTS FOR THERMOCOUPLE LEADS
E—GALVANOMETER SYSTEM
F—CONTACTS INSURING VALVE BEING OPEN WHEN OPERATION IS FIRST STARTED
G—MIRROR, TO AVOID PARALLAX ERRORS IN READING
H—"HIGH" CONTACT CARRYING TUNGSTEN POINT
J—ADJUSTABLE CONTACT TABLE AND TUNGSTEN POINTS
K—INDEX TO SHOW WHERE TABLE IS "SET"
L—BINDING POSTS FOR INSTRUMENT MOTOR LEADS

Fig. 130. Mechanism of controlling millivoltmeter. (*Brown Instrument Co.*)

a normal heat at which the furnace may operate during the greater part of its cycle. Thus the controls are only required to function at deviations from the predetermined normal conditions giving, in general, much greater uniformity of temperatures and atmospheres in the furnace. On large installations, such as pulverizer mills, etc., it is also important from the purely mechanical point of view, to maintain a uniformity of conditions without a too frequent reversal of operation.

On furnaces having low storage capacity of heat, such as forge furnaces, two positions are necessary to control when furnaces change and a third position to close down to a very low heat when furnaces empty. Furthermore, on any furnaces where there is a considerable variation in load, this mode of control in combination with a "balanced" valve-operating motor will automatically adapt the normal position of the valves to take care of complete range of load conditions in the furnace. This eliminates the necessity of resetting the valves to give proper control even at the same temperature whenevdr the size of the charge in the furnace is changed.

In electric furnace control there are definite applications for three-position controllers. For example, a furnace with two windings can be separately controlled in the same manner as outlined for gas furnaces. The same result, however, can be accomplished with a single winding by the application of a time controlling device which controls the power input by interrupting the current at regulat intervals.

Fig. 130 shows the construction of a representative controlling millivoltmeter, the illustration being selected because of its educational value. The maker has contributed the following description of his "trend analyzing" instrument, written with special reference to our discussion (pages 431 to 440) on "Modes of Control."

In the Brown Trend-Analyzing Control Instrument, the slightest motion of the pointer causes the actuation of control contacts without lost motion. The term "follow-up" is used to describe the action of the selector table as it follows the pointer, and any correction in the valve position accompanied by a movement of the selector table toward the pointer is called a "follow-up" correction. By causing the table to follow the pointer, over-correction is avoided, because with each correction the selector table moves along the scale until the center step of the table is at the position indicated by the pointer on the last depression.

If the pointer has moved in the meantime, another correction will be made, but if the pointer has not moved, no "follow-up" correction will be made. It is evident that the "follow-up" corrections are made in accordance with the *rate of change of temperature* and that this action produces a definite valve position for each position of the pointer, and that these corrections tend to oppose any change in temperature. This holds true whether the temperature trend is away from the control setting or toward the desired temperature.

If changing conditions require that *the valve remain in a new position*, the pointer and selector table would also remain away from the control setting if some means was not provided to effect an adjustment of the relative positions of the valve and selector table. This may be accomplished in two ways, either (1) Shifting the table while the valve remains stationary, or (2) Shifting the valve while the table remains stationary. In the Brown trend-analyzing instrument this "compensating correction" is made by the center contact lever in either case. The action of the compensating correction does not depend on the rate of change of temperature, but upon the position of the selector table with respect to the control setting. It recognizes a departure of the selector table from the control setting and functions whenever the pointer is depressed upon the center step of the selector table. These two elements in combination form a control device which recognizes the three factors of (1) Rate of change, (2) Deviation from the control setting, and (3) Direction of trend.

A reversible Warren motor rotates a spiral shaft through a chain and sprocket drive to move the selector table along the scale, following the pointer. The rate of table travel may be adjusted by changing the size of the driving sprocket on the motor. The small reversible motor is connected in parallel with the motor in the valve mechanism and runs simultaneously with it except when the pointer selects the center or neutral contact.

When this occurs, the motor in the valve mechanism is temporarily disconnected and the center contact completes a circuit to one field of the reversible Warren motor. The reversible motor then rotates a spiral shaft which causes the selector table to take a step toward the true control setting.

The trend-analyzing control instrument is designed primarily for use in conjunction with the floating type of valve mechanism. The gradual throttling characteristics are desirable in those applications where the control valve should be moved in very small increments, and where the time lag in the process would produce excessive hunting with the ordinary control instrument with a fixed control table. It may be used in combination with a single motor floating mechanism or with a two-motor floating mechanism. The two-motor trend analyzing control is particularly designed for applications where the control must frequently handle sudden changes in operating conditions.

In general it is advisable to use the single motor valve mechanisms where the time lag is not great and where the primary requirement is to move the control valve very gradually. Use the two-motor mechanisms when the conditions require occasional quick changes in the valve position, or where the process will allow such changes in order to obtain more rigid control. Likewise, the two-motor mechanism is always advisable where there is an excessive or definite time lag.

The Republic Flow Meters Co. has just brought out (July 1930) two new controlling pyrometers, of which this is the first public announcement. One of these will control directly 50 amperes at 220 volts. In other words, it will control 10 K. W. without the use of auxiliary equipment. Due to the large leads which are necessary for this current, the mercury switch and binding posts are placed in a special housing at the bottom of the pyrometer, rather than in the instrument case itself. The other new controlling pyrometer deserves more than a mere mention, and it is our privilege to present herewith its first published description.

The principle of operation of the Republic Control Pyrometer, Model 135, is as follows:

Assuming that the instrument is controlling the heating of a furnace designed for three position control—low, normal and high. Referring to Fig. 131, index 10 is the millivoltmeter pointer which travels across a scale to indicate at all times the temperature of the furnace. A lever 11 pivoted at 12 is vibrated up and down to cause the pointer engaging portion 13 on its free end to beat across the path of the pointer. The portion 13 is provided with steps 14 and 15, a guard 16 and an arm 17. Step portions 14 and 15 are intended to be intercepted by pointer 10, whereby the lever is arrested and the desired regulation of the furnace effected.

It will be seen from the ensuing description that a mere touch of the lever upon the needle is sufficient and for convenience the lever is termed a *tactor*.

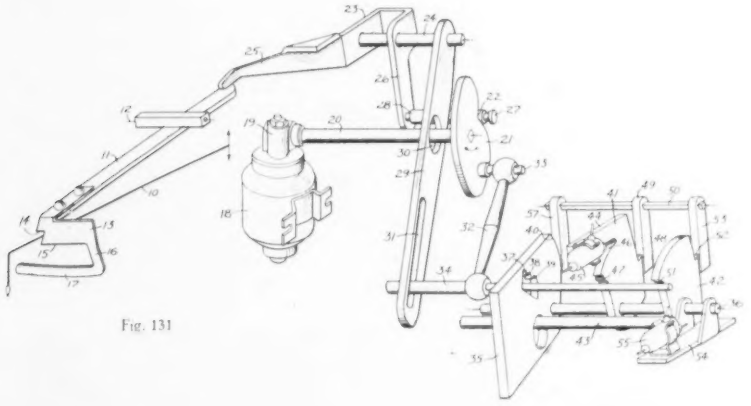


Fig. 131

Through a series of reduction gears 19, motor 18 rotates shaft 20 carrying cam 21 provided with a suitable dwell 22. Cam 21 is connected to the tactor to oscillate the latter through bell crank 23 pivoted at 24. Arm 25 of the bell crank co-acts with the rear end of the lever and arm 26 is provided with a pin 27 carrying a roller 28 adapted to ride upon the periphery of cam 21. The tactor is sufficiently weighted to maintain roller 28 in engagement with the periphery of the cam and as the cam rotates in the direction of the arrow, roller 28 rides into and out of the dwell 22 thereby oscillating the tactor across the path of the pointer. As the roller rides into the dwell, it positions a selector arm 29 in accordance with the extent of oscillation of the tactor. The selector is pivoted on shaft 24 and is provded with a long slot 31 in its free end, the selector being biased toward shaft 20 which acts as a stop to limit its downward movement. An actuator 32, pivoted on pin 33 carried by cam 21, is provided with a pin 34, one portion of which reciprocates in slot 31 of the selector and the other portion of which co-acts with guide 35 pivoted on shaft 36. The guide is provided with notches 37, 38, 39 for retaining and guiding pin 34, as this pin is reciprocating by the rotation of cam 21. Pin 34 is designed to actuate control levers 41 and 42 turning on shaft 36 and normally remaining in position against step 43 which also limits downward motion of guide 35. When the tactor makes a complete oscillation, roller 28 positions selector 29, so that pin 34 engages notch 37 in guide 35 and is caused upon upward movements thereof to move through the cut-away portion 46 of lever 41 and the levers remain in their lowered position with the circuit closed through the switches 45 and 55 as illustrated by the heavy lines in the position marked "low" in Fig. 132. With the switches in this position the control apparatus is operated to turn on the heating medium to the furnace, which will begin to heat up. The described movements are repeated idly while the furnace is heating up and the pointer 10 is consequently swinging from the normal or zero position toward the tactor. Finally the advancing needle swings directly beneath the tactor, the step 14 engages the pointer and further downward movement of the tactor is arrested. Because of the arrest of the tactor, roller 28 does not ride all the way into the dwell 22 of the cam, consequently selector 29 positions guiding pin 34 to co-operate with notch 38 of guide 35 whereupon upward movement of the actuator causes pin 34 to engage detent 47 of lever 41 and elevate said lever which is latched in elevated position by latch 49 engaging ledge 48. Mercury switch 45 now occupies the position marked "normal" in Fig. 132, to reduce the supply of heating medium to the furnace. The temperature of the furnace has now reached its normal, or desired temperature and as long as pointer 10 remains in position to intercept step 14 of the tactor, pin 34 will engage with notch 38, and since lever 41 is latched in elevated position, the pin will reciprocate idly. Should the temperature of the furnace increase beyond that desired, the pointer will swing up scale to engage step 15 of the tactor. When the downward movement of the tactor is thus arrested, roller 28 rides only slightly into the dwell of the cam and the selector 29 positions pin 34 to engage notch 39 in guide 35, whereupon this pin moves up, engages detent 51 of lever 42 and raises this lever to where latch 53 engages ledge 52 and maintains the lever up. Mercury switches 45 and 55 now occupy the position marked "high" in Fig. 132, with the circuit through the dark lines as illustrated.

The heating medium to the furnace is now diminished or cut off and as the furnace begins to cool down, the pointer swings toward zero and soon moves into position to intercept step 14 of the tactor. As before described, when step 14 is intercepted by the pointer, pin 34

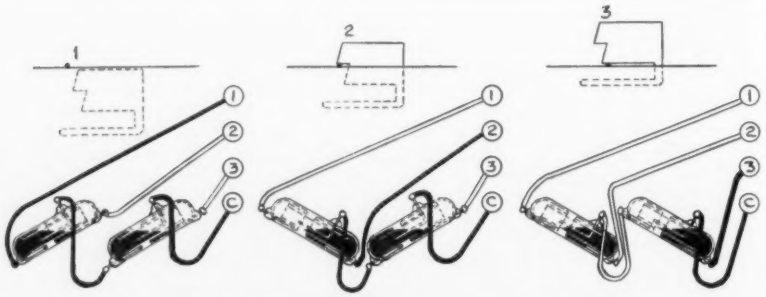


Fig. 132.

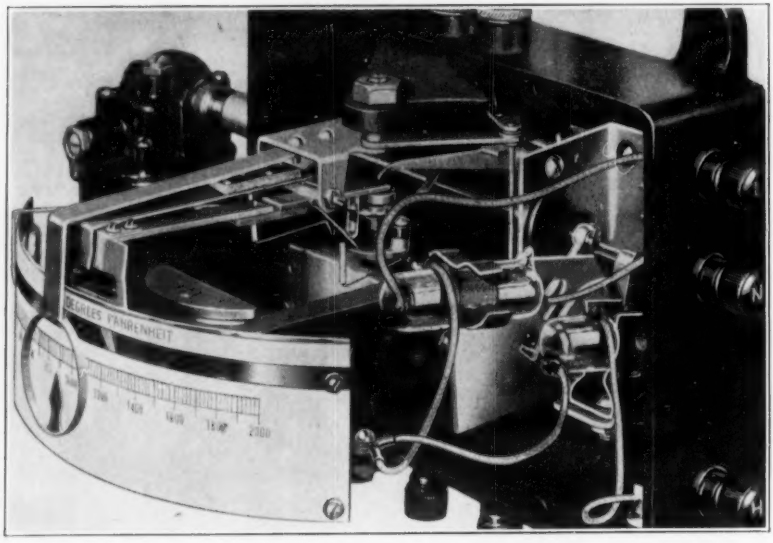


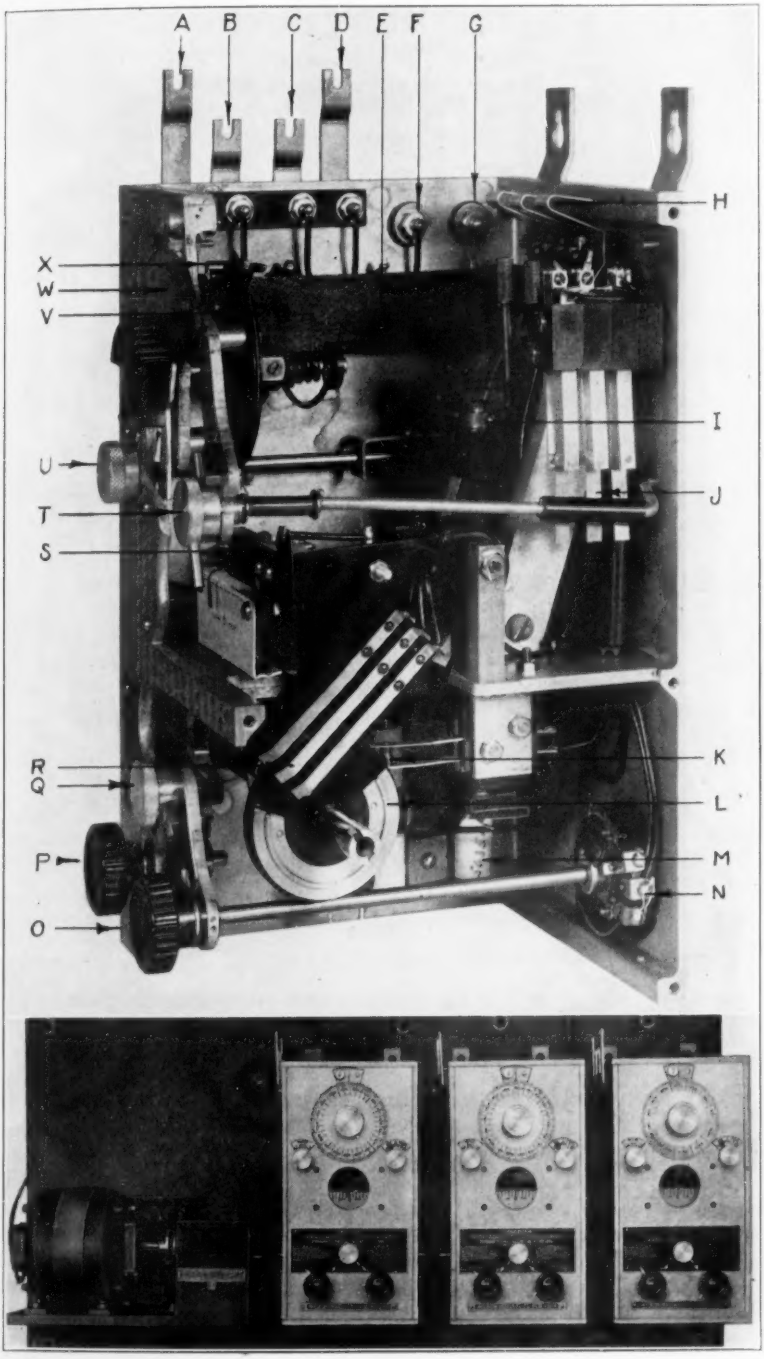
Fig. 133. Controlling millivoltmeter brought out in July, 1930. (*Republic Flow Meters Co.*)

ON FACING PAGE—Fig. 134. Controlling potentiometer, with case cut away, to bring mechanism to view (Instrument especially prepared and photograph made and lettered for this Handbook.)

A—Positive Battery Connection Potentiometer Circuit
B—Negative Battery Connection Potentiometer Circuit
C—Negative Battery Connection Compensator Circuit
D—Positive Battery Connection Compensator Circuit
E—Cold Junction Compensator Coil
F—Positive Thermocouple Terminal
G—Negative Thermocouple Terminal
H—H.C.L. Control Circuit Contacts to Terminals on Top Plate
I—Galvanometer
J—Check Switch (3 Position) for open Circuit and for Standard Cell Check.
K—Auxiliary Switch in Common of Control Circuit. This opens until H & C or L & C brushes (R) of control circuit are connected by rotating contract segment (L) after which closing of electrical circuit is accomplished by this automatic switch K. Similarly electric circuit breaks at switch K before brushes (R) of control circuit leave contact segment (L).
L—Rotating contact Segment on Cam Spindle, which provides selective closed electrical path between brushes of "High and Common" or "Low and Common."
M—Standard Cell.
N—Adjusting Rheostat of Automatic Cold Junction Compensator Circuit.
O—Rheostat Adjusting Knob of Automatic Cold Junction Compensator Circuit.
P—Rheostat Adjusting Knob of Potentiometer Circuit.
Q—Selective Switch for Selecting Check Circuits of Potentiometer Circuit and Automatic Cold Junction Compensator Circuit.
R—Selective Contact Brushes of "High and Common" or "Low and Common" of Control Circuit.
S—Selective Depressor Bar, carrying brushes (R) of control circuit and operated by Cam Spindle Assembly.
T—Check Switch Knob with Spring Return for "Run" and "Open" and "Check" positions.
U—Adjustment Knob for Galvanometer Zero Adjustment.
V—Potentiometer Slide Wire.
W—Temperature Dial which is set to select Control Temperature.
X—Slide Wire Contact Brush.

(*Wilson-Maeulen Co.*)

Fig. 135. Potentiometric automatic temperature controllers, in multiple group, operated by one motor drive unit. As many as eight control units can be operated in a group by one motor drive unit. (*Wilson-Maeulen Co.*)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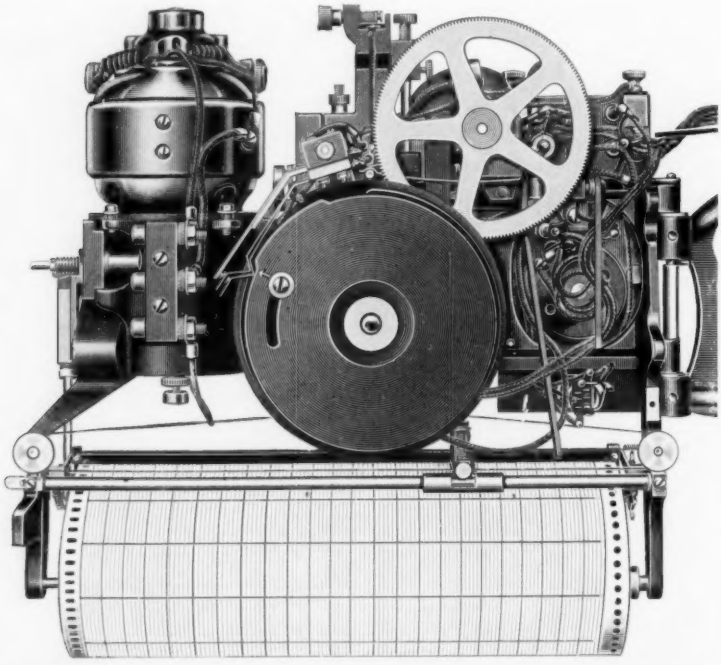


Fig. 136. Mechanism of controlling potentiometer swung out of case. (*Leeds & Northrup Co.*)

is guided by notch 38 of guide 35 and engages detent 47 of lever 41. As the guide moves upward, the cam engaging portion 40, cams arm 57 outwardly, pushing latch element 53 free from ledge 52 and since pin 34 does not engage portion 51 said lever moves to its normal position. This again changes the circuit to that of the position marked "normal," whereupon the heating of the furnace is controlled to bring the temperature back to normal.

Should the temperature of the furnace continue to decrease, the pointer will move down scale beyond the tactor and the tactor will make a complete oscillation and the parts will be operated to the original "low" position, whereupon a greater supply of heat will be supplied to the furnace.

Note that while cam 40 of guide 35 operates latching elements 49 and 53 at each reciprocation, the parts are so synchronized that where pin 34 engages the lever, the engagement is prior to release of the latch subsequent to disengagement of the latch from the lever so that *the lever remains in latched position until there is a change in the temperature of the furnace.*

The weight of the tactor is so disposed that the tactor exerts very little pressure upon the index and the latter is adapted to be supported, during each depression, by the top of the scale plate. Guard 16 prevents accidental movement of the index past the tactor, and arm 17, which normally lies below the top of the scale plate, is momentarily raised slightly above this top after each depression to free the index from its support to prevent its sticking.

(e) Controlling Potentiometers

Refer to indicating and recording potentiometers, parts 3 and 4 of this chapter. Little additional mechanism is needed, the balancing mechanism providing a good start. There are two industrial instruments of this class, the Leeds & Northrup and the Wilson-Maeulen. The former is known in some detail to engineers dealing with high temperatures. It is shown in Fig. 136 which may be compared with Fig. 91, a similar view of the recorder. The latter is not a modified recorder but a special instrument. Its outside appearance is familiar to engineers, but heretofore a view of its mechanism has never been published—which makes Fig. 134 the more interesting.

NEW INSTRUMENTS

Recently Developed by Instrument Manufacturers

Write Information Section, Instruments Publishing Co., Pittsburgh, Pa., for additional Information.

The AC-47 Radio Tube Tester

(Hickok Electrical Instrument Co.)

THIS tube tester is designed to give the radio dealers, jobber and service man a device which will test tubes in a more efficient and complete manner than the ordinary tester, which reads emission only. In order to make its use as simple as possible, it is designed to operate directly from light socket power, and also its indications are independent of line voltage fluctuations. All standard type tubes may be quickly and accurately measured, and for the heater type tubes such as 227, 224, etc., a special preheater can be supplied, which makes the testing of these tubes as rapid as the ordinary filament type.

The dynamic mutual conductance of any receiving tube, is in practically all cases, a most important factor of the tube's successful operation, and if the plate current and dynamic mutual conductance are normal, the tube is absolutely normal in every way, and will give maximum results in radio receiver. The mutual conductance is the most important factor of any tube with the exception of detector tubes, and if this value is nearly normal or

above, the tube will operate successfully even if the plate current is considerably higher or lower than the correct value. The mutual conductance of a radio receiving tube is actually the mutual effect of the grid voltage upon plate current, is found by the following formula:

$$\frac{\text{CHANGE IN PLATE CURRENT}}{\text{CHANGE IN GRID VOLTS}} = \text{MUTUAL CONDUCTANCE.}$$

The AC-47 Tube Tester operates on the above formula, and actually measures the resultant change in plate current from a change in grid voltage. This is done dynamically by applying a.c. to the grid, and reading the resultant a.c. component present in the plate circuit in the form of micromhos.

To accurately test any radio tube, a correct d.c. Plate Voltage must be impressed upon the plate, together with the correct amount of grid bias. In the AC-47 Tube Tester, this condition is accurately fulfilled, and in all cases, the tube is tested under precisely the same conditions as when used in the radio receiving set.

In most counter radio tube checkers, raw a.c. is applied to the plate, which is liable to both injure the tube and give erroneous reading, and as stated above, it is only when d.c. is used at a proper value, together with the proper grid bias, that an intelligent check can be made.

The operation of testing the tube in the AC-47 Radio Tube Tester is very simple, and requires only a setting for the proper filament voltage and a second setting for the proper grid bias. After these settings are made, no further adjustments are necessary in testing a number of tubes, except a slight adjustment of the line voltage rheostat which is only necessary when the line voltage is unstable. A quantity of tubes can be measured as rapidly as they can be inserted in the tester and the readings observed.

On May 30, 1930 P. J. Kipp & Zonen celebrated the centenary of the founding of the company.

The company was started by P. J. Kipp, a chemist, who sold physical and chemical apparatus. His name is known the world over for his invention of the Kipp gas generator.

After his death the business was carried on by his widow and sons, A. J. and W. A. Kipp as P. J. Kipp & Zonen.

Later the company was taken over by J. W. Giltay, who changed the company's name to P. J. Kipp & Zonen (J. W. Giltay, Successor) in the year 1887.

In the year 1912 Mr. Giltay retired and transferred the business to A. O. Ankersmit, who incorporated the firm in 1917 and who still acts as the managing director. The name was changed to N. V. Instrumentfabriek en Handel v/H P. J. Kipp & Zonen.

Type BME Battery Tester

(Roller-Smith Co.)

THERE has long been felt the need of an instrument with which the condition of dry cells could be ascertained quickly in order that dead or nearly dead cells could be eliminated from groups. Also in the selection of cells from a stock it is important to be able to quickly spot any that are not in good condition. Even unused cells in stock do deteriorate and the need of a check, before selling them to the user or putting them in service, is well understood.

The Type BME Cell Tester is an instrument offered to meet the special requirements of this field. It does not show voltage or the current in amperes flowing when applied to a cell, but gives, instead, a reading which shows the relative condition of the cell at the time.

As is generally known there are two common methods used in checking up dry cells, neither of which is satisfactory. They are
(1) The voltage check with a voltmeter.
(2) The current check with an ammeter.

A voltage check does not reveal the true condition of a cell since the voltage will remain up nearly at its maximum during a period when practically no current can be delivered.

The ammeter test, while helpful, short circuits the battery and every test made, therefore, shortens the life of the cell tremendously. Both of these tests have also the added disadvantage that the user must have some knowledge of cell characteristics. Otherwise the readings are more misleading than helpful. The Type BME Tester does not make a dead short circuit on a cell, as in the case of an ammeter which allows 30 amperes or more to flow, but draws only 6 amperes from a new No. 6 cell.

The BME Tester has been designed to make possible the rapid testing of cells without the need of any special knowledge on the part of the user.

The instrument is built without polarity so that no time need be lost in reversing connections as in the case with the majority of battery instruments in use.

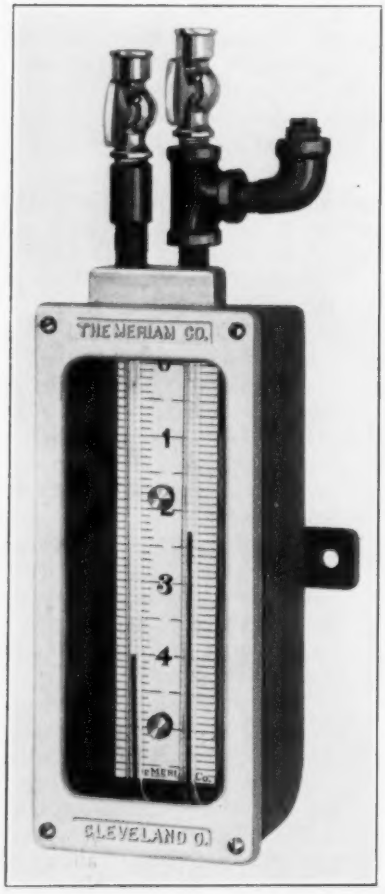
The terminals are spaced so as to fit directly over the terminals of a No. 6 standard cell.

The BME Tester is read by looking directly down upon the top of it, the natural way to read an instrument applied to the top of a No. 6 dry cell.

There are no loose parts. Nothing in the instrument can become demagnetized and with ordinary care the instrument should last indefinitely.

New Well Type Manometer Checks Up Combustion Mixtures

(Meriam Company)

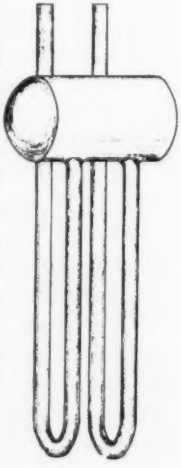


A NOVEL type of flow meter manufactured for measuring the mixture of liquid or gaseous fuel used in furnaces for annealing, heat-treating, heating, chemical and process operating, etc. In practically all such cases, very accurate mixture must be maintained if production results and economy are to be maintained.

The new instrument, which has hitherto been mainly used in the metal-working industries but which is of course adaptable to many others, is made up of a series of compact manometer units. This makes it particulatly adaptable to large groups of furnaces and, being simple and rugged, it is not liable to failure or inaccuracy.

The principles of operation shown in the accompanying diagram. This illustration shows a single manometer unit for measuring the flow of both gas and air to one furnace or group.

The two U-tubes are connected to a single reservoir or "well," which is large in volume compared with the U-tubes, although small in actual cubical content. The well is partly filled with suitable liquid, and the free ends of the U-tubes are connected to pipes tapped off the supply lines of air and of gas respectively. It is evident that although both U-tubes are connected to the same well, their liquid levels will vary independently according to the pressure of the fluid in the supply lines. Units such as described may be assembled compactly in any desired number, and their operation is independent of the distance from the supply line flow to be measured.

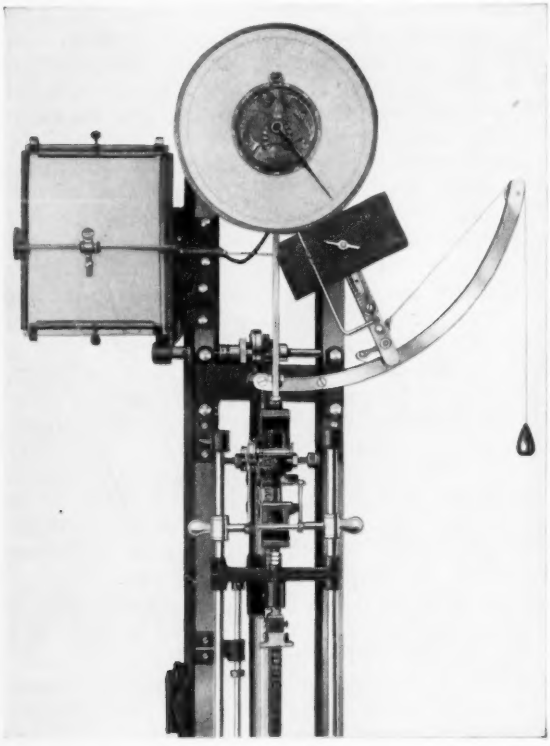


Strictly speaking, the instrument indicates pressure only. However, it can be made to read quantity of flow directly by inserting in each supply line a suitable orifice disc of known dimensions, and having the manometer unit calibrated accordingly.

Calculating Attachment For Textile Tensile Testing Machine

(Henry L. Scott Co.)

THIS attachment comprises a weight adjustable on the balance arm of a tensile testing machine, making possible a direct reading on the dial in accordance with correction factors of any predetermined table. On the balance arm is a scale. The long line in the middle indicates the point at which the weight is set to register actual pounds pull on the specimen.



It is well known that the strength of textiles is changed by the absorption of moisture from the atmosphere. Various formulas for correction are used as accepted practice and in some cases are specified. When tests are made on a machine which does not have this calculating attachment, the results are in terms of pounds pull on the specimen. It is then necessary to compute these results to determine strength at normal regain.

In the case of cotton yarn, it is generally accepted that for each 1% gain in moisture there is a gain of 6% in strength, in the ranges of zero to 11% or 12% regain, which embraces the range that atmospheric conditions affect the strength of manufactured cotton goods. There are many variations of this formula and many differences of opinion.

The calculating attachment provides a ready means for accomplishing this result in accordance with any formula for correction of tests, to a basis of any standard condition which may be accepted by the parties concerned.

Single Strand Yarn Tester

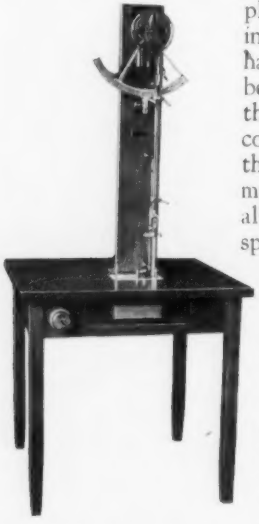
(Table Model)

(*Henry L. Scott & Co.*)

THIS machine, designed for single yarn testing, is in the form illustrated to increase the efficiency of the operator. It eliminates from this tedious process the physical exertion necessary in operating the older types of apparatus.

The tester is mounted through a heavily constructed oak table 30″ square, in such a way as to permit control while the operator is seated. There is a drawer in the table for the convenient holding of calibrating weights and other accessories.

The head of the machine is on the inclination balance principle using a sector rather than a single lever or a full wheel type of resistance. This is delicately poised on pivot point bearings completely enclosed, and because of this protection insures long life. The machine is rigidly built and has a new and novel type of gear box, the clamp being carried on the top of a steel rack, and the three buttons are under the operator's hands for control—stop, start and reverse. The drive is through a 1/30 h.p. motor and on the standard machine the pulling speed is 12″ per minute, although this latter can be arranged on other speeds if specified. It is also possible to provide two or more speeds in the single machine where desired.



The clamps are of a cam-operated design, having flat grips. The upper clamp is counterbalanced and the head parts, being of aluminum, have considerable less inertia than the ordinary construction; consequently, the machine is much more accurate on the lower readings. The pawls which hold the reading at the break are so arranged that there is a minimum of drop-back, yet they are instantly released.

The standard machine is built in the double capacity of 0-2, 0-10 pounds. The change from one capacity to another is made by adding or removing a small auxiliary weight on the lever. The graduations on the 2 pound scale are in .02 of a pound and on the 10 pound scale in .10 pound of units. The zero point is not affected when the change is made.

A new arrangement of pointer is incorporated in the design of this machine, so that the scale which is not in use is covered, and thus eliminates any chance of reading the scale that does not correspond to the capacity being used. The stretch indicator is arranged to be carried only to the point where the break occurs. New construction features are incorporated to leave this stretch indicator at the point of stretch at break. This automatically resets with the reverse of the machine. For example—the operator inserts a sample, pushes the button at the start of the test, stops the machine after the break occurs, takes the reading of stretch and elongation, pushes the button, and the machine resets itself instantly for the next test.

The Determination of Gas Heat Value

Dr. Loeffler, Vienna

THE many instruments, which can be used for this purpose, are divided into portable and permanently installed, respectively recording calorimeters. Under the assumption, that a portable instrument should be constructed in such a way that it can be used without preparation at every place where combustible gas is available, to determine the heat value, Strache for the first time used the idea of the ignition of a gas-air mixture and transmittal of the heat released to a thermometer. The calorimeter built on this principle is called the "Kaloriskop." It permits the instantaneous determination of the heat value of all combustible gases of 900-13,000 cal./m^3, with an accuracy of $\frac{1}{3}\%$. The simple operation and rugged construction have led to the rapid introduction of this reliable instrument for operation control.

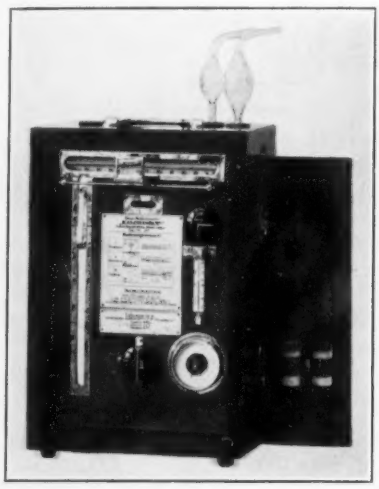


Fig. 1

Its construction is shown in Fig. 2, its external appearance in Fig. 1.

In a double walled sphere, the space between the two spheres being highly evacuated, is placed a very thin-walled glass bulb of a mercury thermometer. The scale of this thermometer is illuminated by placing a light behind it and the position of the mercury thread easily read through a movable reading glass. A pipette of any size can be clamped to the apparatus with a spring. The gas can be passed through this pipette under its own pressure or by means of a leveling battle after first passing through a filter. The pipette is closed by a capillary, so that the gas is protected against diffusion for a short time. By means of a leveling battle mounted on a slide the gas collected in the pipette is drawn into the explosion-chamber and there mixed with air. It is evident that by the proper choice of pipettes different mixtures of gas and air are obtained.

The ignition of the mixture is accomplished with an induction spark, the current source is a small dry cell. A control lamp is provided to check if the spark has passed. A mercury switch prevents the ignition from taking place, when cocks are open, thereby permitting the heat to escape. The whole instrument weighs about 4 kg, and is 35 x 24 x 16 cm. It does not require a water supply, waste outlet, or outside current source and can be used at any place, a point which is especially important in practice.

An important point for the operation of the instrument is that the gas-air mixture be chosen so that it lies within the explosion limits, especially that it lies within the limits of total combustion. If the gas is wholly unknown, one can easily determine the proper values by using different pipettes. The following relations can be obtained: 1:1; 1:2; 1:3; 1:5; 1:7; 1:9;

1:10. It is always possible to obtain similar values with adjacent pipette ratios, as all industrial gases have sufficiently wide limits of complete combustion.

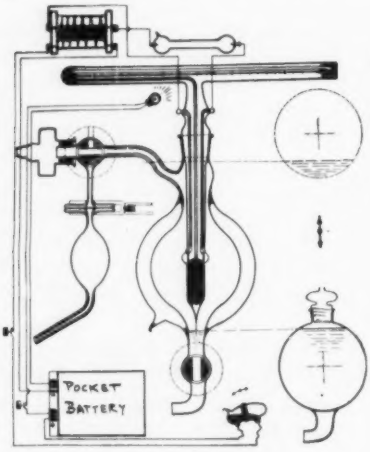


Fig. 2

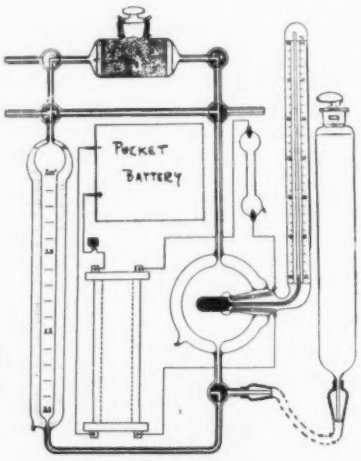


Fig. 3

In order to provide an instrument for the laboratory, which exceeds the accuracy limits required in the plant, the micro-gas-calorimeter (see Fig. 3) was built. The principle is the same as for the Kaloriskop, the construction is different in that in place of water in the leveling battle, mercury is used. Further in place of using different pipettes, a water-jacketed burrette permits measuring any volume of gas. The micro-calorimeter also has an arrangement for absorbing CO_2, so that the instrument can make the following determinations with small quantities of gas:

1. Upper heat value.
2. Lower heat value from contraction after ignition.
3. CO_2 content of gas.
4. CO_2 content of burned gases.
5. The explosion limits of the gas.
6. The limits of complete combustion.

The connecting pieces between the individual parts of the apparatus consist of fine capillaries and also are completely filled with mercury, so that every space which may cause error is avoided. The instrument can make 3-4 heat determinations with about 20 cc.

Wanted—Aeronautical Instrument Designer

Designer of aeronautical and special research instruments with previous experience in the manufacture and testing of delicate instruments or clock works and the movements of mechanical and electrical measuring devices.

Goodyear-Zeppelin Corporation, Akron, Ohio

Address—Mr. Hendershott,
Manager of Office Employment Department

Differential Limit Controller Applied to Metering Widely Varying Flow

THE satisfactory measurement of widely varying flow has always been a troublesome problem, particularly to the Natural Gas Industry. The Foxboro Company has perfected a new instrument called a differential limit recorder-controller. This controller, when working with the Foxboro gas meter in the type of installation shown in Fig. 2, will successfully meter flow that is varying over so wide a range that even a wide range meter will not allow satisfactory readings.

Once installed, the differential limit controller continually gives a record of the gas flow through the line. This controller is known as the primary meter (See Fig. 1). It is specified to handle the minimum rate of flow with commercial accuracy. When the differential range is exceeded, the control functions and automatically opens a valve which puts the secondary meter in operation. This secondary meter is a complete Foxboro gas flow meter operating in the by-pass. When the secondary meter goes into operation it doubles the effective capacity of the set up.

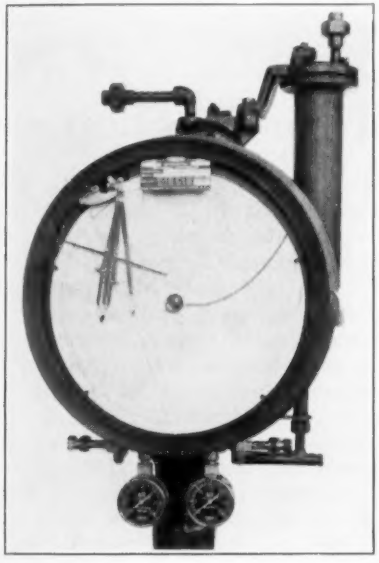


Fig. 1

As soon as the secondary meter line is open the differential pressure drops, because of the increased capacity. The valve in the secondary meter line is held open by the controller until the flow is again within the capacity of the primary meter. The valve is then closed automatically and the primary meter again assumes the entire load. The operation is entirely automatic from start to finish.

Positive and flexible control is obtained by the fact that the points, at which the secondary meter is to be cut in and out of the line, can be set at will. Positive action and tight closing of the controlled valve are insured by having it operated by the gas line pressure or an auxillary air supply of 15 lbs. /in^2.

Single meters or wide-range meters or more than one by-pass may be installed in various combinations with the new differential limit controller to meter all cases of varying flow. With this new development, the troublesome problem of correct metering wide range flow has been relegated to the past.

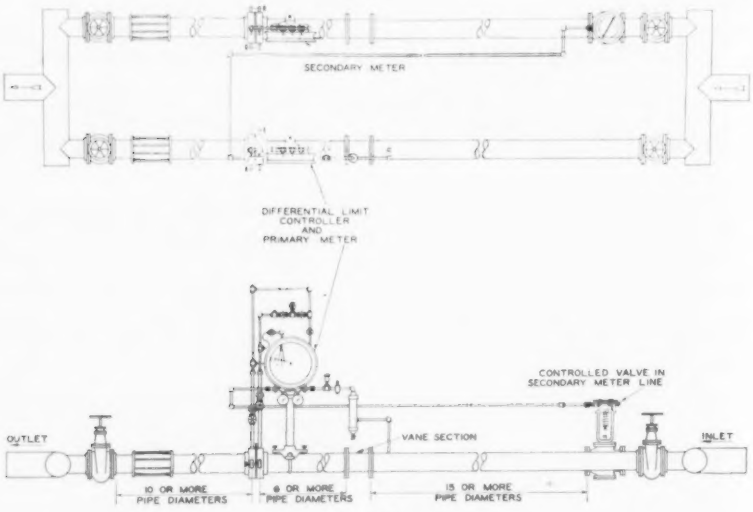


Fig. 2

A New Microscope For Shop Inspection Use

SURFACE conditions can readily be inspected with a new shop microscope which has recently been placed on the market by the Bausch & Lomb Optical Company.

The No. 32 Shop Microscope, designed for rapid examinations and measurements of surface characteristics, is a small, portable and rugged instrument admirably adapted for the machine bench or inspection table. It is also particularly well adapted for use by salesmen in pointing out minute details of construction or perfections in finish and such other fine points which can not well be seen by the unaided eye.

A scale in the eyepiece, calibrated in thousandths, which is one-tenth of an inch long, enables the operator to measure the crack, flaw or other characteristic under examination to determine its quality or adherence to precise specifications. With exact measurements of a thousandth of an inch made possible, a quarter of a thousandth is easily estimated.

The shop microscope magnifies 40 times and has a field up to 7/32." It is self-illuminating. The instrument is 7 3/4" high and weighs only 1 1/2 pounds. It is in black enamel and chromium finish.

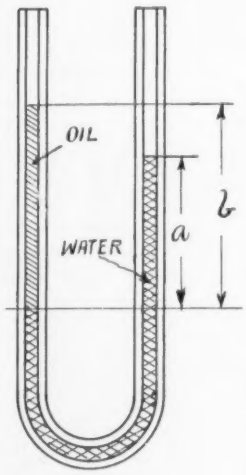
A Simple Method of Measuring the Specific Gravity of Liquids

*J. B. Meriam**

FROM time to time the engineer is faced with the problem of determining the specific gravity of a liquid. The problem being one which is as a rule outside the ordinary routine work, it is quite likely that no float hydrometer of suitable graduation is available, and the test has to be made with whatever apparatus happens to be at hand.

It is not, I believe, generally known that any ordinary U-tube manometer, such as is used for determining the flow and pressure of air, gases and liquids, may be used for the purpose of showing the specific gravity of liquids—and such an all-around testing instrument as a manometer is generally available.

The method is as follows: Both ends of the U-tube being open to the air, pour a small quantity of the liquid whose specific gravity is to be measured into one arm of the tube, and the standard liquid with which it is to be compared into the other. It is not necessary to measure the quantities of each, as the relative proportions have no effect on the accuracy of the test. Since the specific gravities of all liquids are based upon that of water as 1.00, it is preferable to use water as the standard of comparison when practicable.



In accordance with the law of gravity, the two liquids will of course establish a balance If therefore the specific gravities were equal, the liquid levels in the two tube-arms would also be equal in vertical height. If different in specific gravity, however, it will require a greater height of the lighter liquid to balance the heavier liquid in the other arm. The difference between the two levels in proportionate to the difference in the specific gravities of the two liquids.

To take a typical example—to find the specific gravity of a sample of oil. Since oil and water do not mix readily, the water, being heavier, should first be poured into one arm and the oil into the other. The height of the water column divided by the height of the oil column will give the specific gravity of the oil. Thus if the height of the oil column is 12 inches and that of the water column is 10 inches, then the specific gravity of the oil compared with that of the water is 0.834. Water being 1.00 no further calculation is necessary.

It is interesting to note that not only is this method fully as accurate as that of a regular float hydrometer but also that its reliability is not affected by the internal diameter or length of the U-tube, the quantities of each liquid used, or any other factor likely to be met with in a "rough and ready" shop test. It depends only on gravity; the formula being equally true

* President, Meriam Company.

whether the tested liquid is lighter or heavier than the standard of comparison.

Where there is a tendency for the water to mix with the liquid under test a double test must be made. For instance, it would be difficult to prevent water and alcohol from mixing, no matter how carefully they were poured in. But since water and kerosene do not mix readily, the specific gravity of a kerosene sample may be obtained. This kerosene will not mix with alcohol, and these two may next be compared by using the same formula.

Junior D. C. Multimeter

(Rawson Electrical Instrument Co.)

JUNIOR is the very latest addition to the Rawson Multimeter family, which are now so well known in practically all of the largest laboratories in the country. This sturdy youngster bids fair to become extremely popular in the smaller laboratories where first cost is an important item.

The scale of this meter is about three inches long, divided into 100 subdivisions, figured 0 to 100 and 0 to 2. There are twelve ranges covering readings from two microamperes to one ampere and from twenty microvolts to one thousand volts in easy overlapping stages. In fact for the research engineer delving into unknown quantities this little meter is ideal.

The high resistance of one thousand ohms per volt, extending up to one megohm on the one thousand volt range, should appeal to the engineer where small power consumption is important, while the maximum resistance on the current ranges is only ten ohms extending downwards to .001 ohm on the one ampere range.

Only three binding posts are employed; one common, one for current and one for voltage, all the ranges being controlled by a well designed selector switch with a decided click in each position. All ranges are plainly engraved.

A special feature of this meter is the lowest two ranges in millivolts being two and ten, having a constant resistance of ten ohms. This arrangement is especially suitable for use with Rawson Thermo Couples in Vacuo for high frequency work. The combination of these two ranges provide readings over the whole workable range of the thermo couple and the constant resistance feature provides perfect overlapping of scales. Readings on radio frequency currents as low as 200 microamperes can be made using the two millivolt scale.

The standard meter is supplied with regular single pivot movement having zero shift and clamping device easily operated by knurled buttons. Patented double pivot movement with zero shift and clamping devices as above can be supplied at a slight additional cost. The case of meter is die cast aluminum with black crackle lacquer finish which is very tough and durable.

The accuracy is guaranteed to one-half of one percent.

Size 5″ x 4⅜″ x 2⅛″, height over all 3″.

New S. &H. High Tension Fault Finder

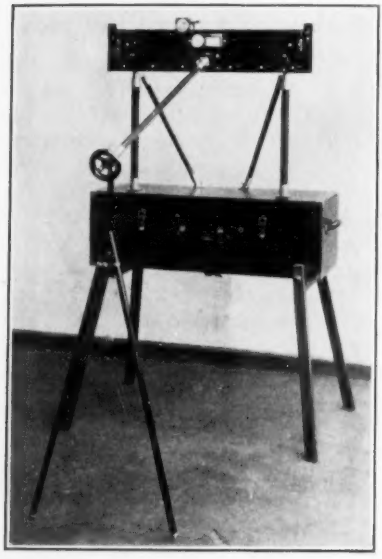
(Herman H. Sticht & Co.)

IN the modern system of power distribution, it is of the utmost importance to be able to locate faults in the cable system as quickly as possible. These faults may be open circuits, short circuits between phases or grounds.

The location of an open circuit taking place without a ground is of course easy to locate by the well known method of measuring the capacity of the two sections of the cable.

The new instrument is used for the location of grounds or short circuits between phases.

For this class of work, the ordinary low voltage Wheatstone bridge or the fault finding bridge has not been found satisfactory. Even when these bridges were used with 100 volts, it was impossible to locate the fault if it had several thousand ohms resistance. The measuring current under such conditions is so small that even with the most sensitive mirror galvanometer it is not sufficient to get an exact measurement. While the fault when first experienced may have been comparatively low in resistance, due to the heat influencing the insulating material, by the time that the bridge is set up and the measurement made, the cable is generally cooled and the resistance increased.



As a consequence, many central stations have found it necessary to first apply high voltage alternating current to thoroughly break down the fault before using the fault finding bridge. Even with this method there is frequently a tendency for the resistance to increase in the time between the application of the high voltage alternating current and the test with the bridge.

In the new Siemens & Halske High Tension Fault Finder, the two steps in the process of finding a fault are combined. The instrument is shown completely set up in the illustration, and is used in connection with a kathode ray rectifying device, such as the well known Kenetron, furnishing up to 50,000 volts D. C.

This high tension fault finding bridge permits of a rapid and accurate location of the faults in cables.

The high tension measuring bridge is designed on the well known principle of the Wheatstone bridge. The measuring wire and all other

parts are mounted on a highly insulated molded composition panel. The panel is insulated against the earth by tubes made of similar material, so that the instrument will safely withstand tests on voltages up to approximately 50 KV. The sliding contact comprises a silver roller in a carriage, which slides on the wire. This slider is fed with a high voltage current from a rectifier as mentioned before, with one pole connected to the ground. The slider can be safely adjusted by means of a grounded wheel on the end of an insulated rod, which is connected to a ball joint, the latter in turn actuating the roller with cord connection on the slider. Since both the galvanometer and the slider are provided with lenses, readings can be conveniently made from a distant point.

The bridge has three ranges to cover the various lengths and sizes of cable. The fault finder is made collapsible, so that the whole outfit may be carried in the case shown in the illustration.

A New Small-Motor Starting Switch

(Cutler-Hammer, Inc.)

THIS new starting switch can be used with d. c. motors up to 1/2 H. P., 115 volts and 1/4 H. P., 230 volts or with a. c. motors—single, two or three phase up to 2 H. P., 110 to 550 volts. Small in size,—the enclosing case is a standard wiring box—the switch can be mounted right on the machine, at the operator's finger tips. For machinery builders, an open type switch for building directly into the machine, is offered.

Double-break, silver contacts and a quick break contact mechanism assure long life and continuous current carrying capacity. The thermal overload relays allow working the motor to the limit—yet disconnect it as soon as an overload becomes dangerous to the motor. When tripped by an overload, simply pushing the "reset" button resets the relay and starts the motor. The enclosed switch has conduit knockout holes in the top and bottom for easy wiring. Arrangements are provided for sealing the cover if desired.

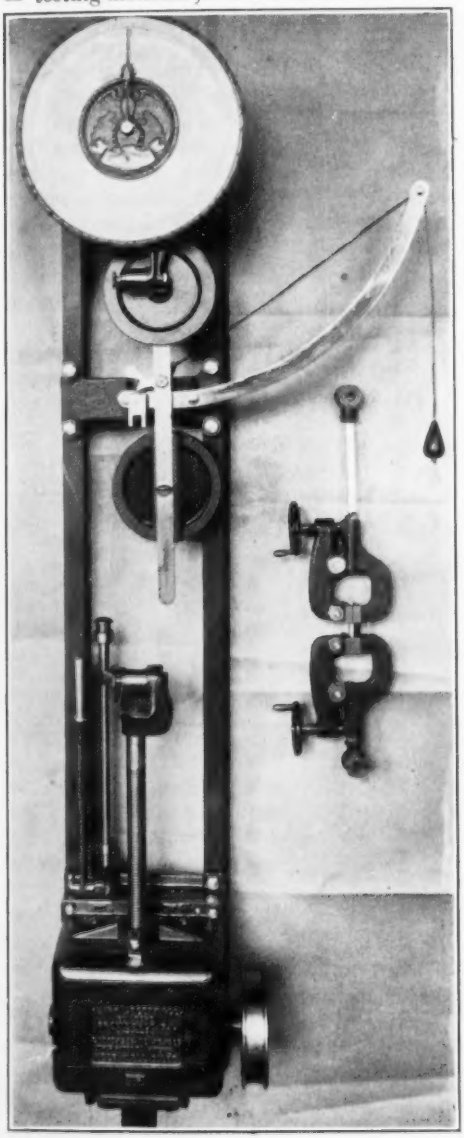
ANNOUNCEMENT is made by Culter-Hammer, Inc., Milwaukee, Wis., that on July 1st, they acquired all common stock of Schweitzer & Conrad, Inc., Chicago manufacturers of high voltage equipment. Schweitzer & Conrad will continue to operate as an independent manufacturing and selling unit. No changes in organization or personnel will be made except Mr. Beverly L. Worden, President of Cutler-Hammer has also been elected President of Schweitzer & Conrad. Mr. Conrad and Mr. Schweitzer have been retained as consulting enginers and will continue their interest n the management as members of the Board of Directors. Other members of the new Schweitzer & Conrad board are Mr. F. R. Bacon, who is Chairman of the Culter-Hammer board and Mr. F. L. Pierce and Mr. Louis A. Lecher who are also members of the Culter-Hammer board.

Combination Tester

For Yarns, Twines, Cloth, Paper, Etc.

(Henry L. Scott & Company)

IT is a well known fact that variations in the speed of separation of the testing machine jaws affects the tensile strength of any material. The general accepted speed specification is that the draw bar or stretching screw shall move at the rate of 12″ per minute for most textiles.



Hand operated machines are satisfactory for making approximate comparisons when operated under comparable conditions. Such conditions are practically impossible of attainment between two operators. Power operated testers should be used where accuracy is desired and particularly when it is desired to check values between different organizations.

Power operated machines are driven through a speed reducing attachment by a ¼ H.P. motor placed on the floor beneath the tester. Power may be taken from any convenient light socket. Variations in speed are thus eliminated. This insures the testing of every sample under identical conditions.

This machine is built on the "dead weight" principle. There are no fluids to leak or springs to adjust.

The pendulum swings on ball bearings, therefore, practically without friction. The force exerted through the sample raises the pendulum, the pull in pounds being indicated by the pointer on the dial.

The toothed rack is 1″ wide with teeth spaced 12 per 1″. Six gravity pawls travel on this rack and hold the pendulum in the position at break until reset by raising the pawls and returning the pendu- lum to the vertical position.

All moving parts are of heavy construction, carrying a large limit of safety, and are well enclosed.

The stretching screw operated smoothly and passes through the gear box without revolving. This is an important feature as it obviates the possibility of yarn becoming entangled in the moving parts.

The machine is operated by two levers, one for starting and the other for reversing and stopping. The machine is started by pulling the "starting lever" forward and immediately releasing it, allowing it to return to its original position. Pressing down on the combination reverse-stop rod reverses the machine at about twice its downward speed Pulling up on the same rod stops the machine. The automatic reversing and stopping of the machine is accomplished by means of an arm attached to the stretching screw and sliding on the reverse stop rod between two adjustable collars. The lower may be set to reverse, and the upper to stop the machine at any desired point. In this way the jaws may be set any desired distance apart and after each test the machine will automatically reverse and stop at the original starting position.

A New Portable Immersion Pyrometer

(Illinois Testing Laboratories, Inc.)

REPEATEDLY, foundrymen have stated "Pouring metals at the wrong temperature is like pouring Dollars in the Scrap Pile." Perfect castings—castings having fine grain structure, resulting in superior strength, uniform in size requiring minimum machining, are natural results when correct pouring temperatures are used.

Excessive losses, both fuel and metal, are caused when the pouring temperature is either too hot or too cold.

Progressive foundrymen have long felt the need for an instrument which can be used in production for the accurate measurement of molten nonferrous metals.

Present types of pyrometers available for this purpose accomplish this result only partly—unless the measurement is obtained by skilled operators.

All commercial forms of pyrometers available for this service operate on the thermo-electric principle using either a thermo-couple of the open wire type or one completely enclosed in a heavy protection tube.

Utmost accuracy of reading is obtainable with the totally enclosed type of thermo-couple, because it is not affected by the slag, dross or other surface conditions of the molten metal—however, unfortunately, the heavy wall of the protection tube introduces considerable lag, necessitating a longer period of submergance before a constant reading is obtained—obviously, the long time required per reading is not desired by the production man, therefore, this type of thermocouple has been more of a laboratory means for obtaining high accuracies.

Pyrometers having the open wire type of thermo-couple are in common use in most foundries because this thermocouple responds quickly to the temperature of the molten metal.

Unfortunately, slag and dross affects the conductivity of the open wire thermocouple at the surface of the molten metal causing the pyrometer to give incorrect or variable readings unless the surface was specially prepared.

Occasionally, due to the slag and dross brought about by special fluxes, an electrolytic action is set up in the thermocouple causing the pyrometer pointer to deflect beyond the full scale.

Also, an open type of thermocouple can never indicate the true temperature of the molten metal below the surface due to the short circuiting action of the liquid metal—the surface temperature, invariably is always 15 or more degrees less than the temperature below the level.

Considerable difficulty is usually experienced by the unskilled user of a pyrometer having the conventional open thermocouple—unless all of the slag and dross are removed from the surface of the molten metal and also when the thermocouple wire tips are properly cleaned in order to get intimate electrical contact with the liquid metal.

In order to overcome the known difficulties of measuring molten nonferrous metals, a self-contained portable pyrometer known as the "Alnor" Pyro Lance which is equipped with a special enclosed type of thermocouple having the quick response of the conventional open couple and the accuracy of the standard enclosed unit, has been developed.

This improved enclosed thermocouple will consistently give accurate readings within 30 seconds after immersing the tip in the molten metal.

An unskilled operator, with this instrument, can obtain precision temperature readings of the molten metal quickly, merely by dipping the tip of the thermocouple into the liquid metal.

All readings will be immune to the surface conditions—slag, dross or electrolytic action will not cause a variable or inaccurate result.

Furthermore, the temperature may be measured at any depth, merely by controlling the depth of submergance of the thermocouple tip.

Another feature in this pyrometer which appeals to all users is the convenient means available for adjusting the thermocouple to any angle, making it suited for all types of furnaces and crucibles.

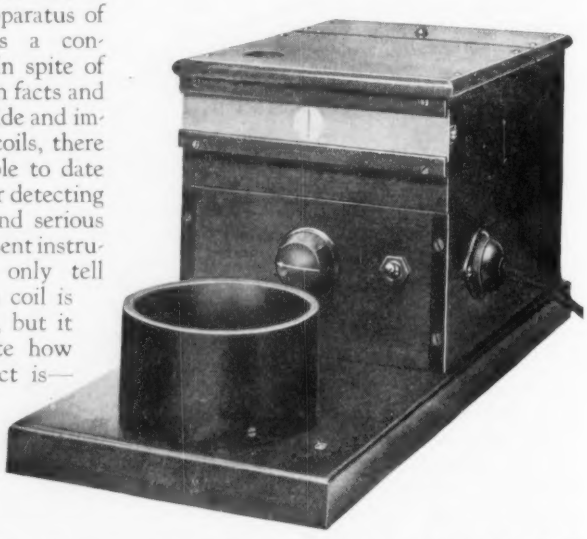
Whenever the occasion necessitates a new thermocouple, it can be quickly inserted by the user without the aid of any special tools or skill.

The steadily increasing demand for pyrometers, flow meters, and other industrial instruments manufactured by The Brown Instrument Company of Philadelphia, Pa., necessitated additions to their plant in 1928 and 1929. The continuing growth of the business having again justified expansion, The Brown Instrument Company has just let a contract for 40,000 square feet of additional floor space.

New Coil Testing Instrument

THE RUBICON COMPANY announces the Rubicon Coil Tester—an entirely new instrument for detecting the presence of short-circuited turns or defective insulation in coils and windings of all kinds.

A coil containing one or more short-circuited turns or one in which the insulation between terminals is impaired is justly considered an electrical hazard. Such a coil invariably results in improper functioning (and often even in complete breakdown) of the apparatus of which it forms a constituent part. In spite of these well known facts and in spite of the wide and important uses of coils, there has been available to date no instrument for detecting these common and serious defects. The present instrument will not only tell whether a given coil is defective or not, but it will also indicate how serious the defect is—how many turns are short-circuited or how badly the insulation is impaired.



The Rubicon Coil Tester consists of a vacuum tube circuit with which is associated a reflecting galvanometer of very short period. The tube with its necessary circuit elements and the galvanometer with its optical system are all enclosed in a neat walnut cabinet measuring approximately 9x8x7 inches. An extension in front of the instrument carries the so called "test cup"—a hollow bakelite cylinder within which are placed the coils to be tested. Indications are given by a spot of light on a ground glass window.

Normally the galvanometer carries no current and the spot of light indicates zero. But when a coil of wire, having one or more short-circuited turns or one in which the insulation between terminals is imperfect, is introduced within the "test cup" or placed around it, the resulting absorption of energy destroys the circuit equilibrium and brings about a displacement of the spot of light, and this displacement is a measure of the seriousness of the fault.

Being very sensitive the Rubicon Coil Tester is at the same time a very sturdy piece of apparatus especially designed to withstand rough shop usage. The galvanometer has a period of only 1/2 second, and since no electrical connection need be made between the coil and the instrument, the speed of testing is practically unlimited.

The Coil Tester is offered in two models, one for operation on 110 volts, 60 cycles alternating current and one for battery operation.

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POTENTIOMETER PYROMETERS. Separate leaflets cover the operation of potentiometer pyrometers in coke plants, in cement mills, in railroad shops, in glass plants, and in refrigerating plants. Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.

RADIO CONDENSERS, COILS AND RESISTANCES. An engineering manual furnishing information on condensers, radio coils, resistances, grid leaks, connectors, coils, enameled copper wire. Polymet Manufacturing Corp., 829 East 134 Street, New York, N. Y.

BAKELITE REVIEW. The April 1930 issue of this periodical contains illustrations showing the application of Bakelite to electrical instruments, etc. Bakelite Corp., 247 Park Ave., New York, N. Y.

GROUND RESISTANCE TESTING. Technical Bulletin 1260 covers the measurement of the resistance to earth of ground connections. James G. Biddle, 1211 Arch Street, Philadelphia, Pa. Price, 50 cents.

THE GENERAL RADIO EXPERIMENTER. The April issue of this paper contains: A tuning-Fork Audio Oscillator; An Audio Amplifier for the Laboratory; General Radio Company, Cambridge, Mass.

TACHOMETERS. Catalogue 300 illustrates and describes the following types: Mecurial indicating and recording tachometer, stationary tachometers, hand tachometers and speed indicators. Amthor Testing Instrument Company, 309 Johnson Street, Brooklyn, N. Y.

ORIFICE METER. Catalog LF-1 contains information on the features of construction and operation of the Linderman Orifice Meter. American Meter Company, 105 West 40 St., New York, N. Y.

COMBINATION PRESSURE AND TEMPERATURE RECORDER. Leaflet illustrates and gives drilling and over-all dimensions of the 10" Tag Recorders. C. J. Tagliabue Mfg. Co., 18 Thirty-third Street, Brooklyn, New York.

THERMOPILES. Chart gives sensitivity data of thermopiles. P. J. Kipp & Zonen, Delft, Holland.

SPEED IN INDUSTRY. Bulletin 5301 illustrates the recording of speed in steel mills, newspaper plants, cement mills, glass plants, heat treating plants, etc. Esterline-Angus Company, Speedway Ave., Indianapolis, Ind.

WATER WORKS JOURNAL. The May issue contains: A $12,000,000 Drinking Cup for St. Louis; General Information Pertaining to the Development of Portland's Water Supply since 1917. Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

AUTOMATIC CONTROLLERS. A series of leaflets issued by Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa., have the following titles: Kiln Operators Can Produce Better Ware; Improve Blast-Furnace Production; Process Operators can Produce Better Products; Galvanizers can Produce Better Ware; and Railway Shop Foremen Can Turn Out Better Parts.

CALORIMETRY. 30 page booklet, a discussion of calorimetry, also describes the American calorimeter and gives instructions for operation. Calorimetry Bulletin A2. American Meter Company, 105 West 40 Street, New York, N. Y.

AUTOMATIC TEMPERATURE REGULATION. 40 page bulletin devoted to the automatic raditor valves. Direct Control Valve Company, Chicago, Ill.

GAS SERVICE JOURNAL. The May issue of the Gas Service Journal contains the following: Pressure Loss in Gas Meters; Higher Investment vs. Higher Operating Cost; The Determination of the Friction Factor in Long Pipe Lines. Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

GENERAL RADIO EXPERIMENTER. The May issue contains: The Dynatron, and Uses of Power Level Indicators. General Radio Company, Cambridge A, Mass.

HUMP HARDENING FURNACE. Leaflet Heat Treating Series, Piece No. 25, Hardening illustrates carbon steel tools hardened by the Mueller Brass Co. Leeds & Northrup Company, 4901 Stenton Ave., Philadelphia, Pa.

LABORATORY. Vol. 3, No. 3 reproduces a painting "The Alchemical Making of Medicine, in the 16th Century; also contains new apparatus descriptions: A Beaker Gage; a new Hydrogen Sulphide Generator, the Euscope; the new Davis-Brandt Molecular Weight Apparatus; new Meniscus Reader. Fisher Scientific Co., 711 Forbes St., Pittsburgh, Pa.

MICROSCOPE RECORD. The May issue contains the following articles: Current Microscopy: Some uses of the Dark-Field Condenser; Unusual Diatom Forms; Dr. Robert Koch on the Abbe Illuminator; The Mounting of Freshwater Algae; Recording Photomicrographs. W. Watson & Sons, Ltd., 313 High Holborn St., London, WC1, England.

IRON CASE GAS METERS. Catalogue EG-40 describes the Metric Iron Case Meters for low and high pressures. It also contains data on sizes, types, capacities, dimensions, etc. American Meter Company, 105 West 40 St., New York, N. Y.

CURRENT LITERATURE REVIEW

Abstracts on instruments and devices for measurement, inspection and control.

The Technology Department, Carnegie Library, Pittsburgh, Pa., will furnish photostats of material abstracted here. Negative prints are 35 cents per page, plus 10 cents for mailing (first class). All orders should be paid in advance. The library is not responsible for loss in mails

PRESSURE

The Engine Indicator as a Guide to Performance. H. A. Gehres, Cooper-Bessemer Monthly, Jan. 1930, pages 3-5, 20.

This series of articles describes the engine indicator and discusses its application. Interprets the indicator diagrams.

The Fuel-Injection Process in the Air-Injection Oil Engine. J. S. Brown. Journal Royal Technical College, Jan. 1929, pag s 81-99.

By a novel method of applying the engine indicator on an air-injection oil-engine, features are brought out which show that the system of measuring each fuel charge at the fuel-pump does not lead to these fuel charges being passed into the cylinder as separate and complete injection quantities. The charges are passed from the pump to the pulverizer unit situated within the body of the fuel valve, and it is traced that part of each charge is retained on the lower levels of the pulverizer to form a contribution towards the injection quantity of the next following working cycle. It is then brought out that the indicator shows that this carried-over fuel enters the cylinder in advance of the residual quantity which comes directly from the fuel pump. It is thus shown that there are two separate phases in the air-injection process, which tend to be separated by some short time interval: and a satisfactory explanation is afforded of the feature of constant pressure combustion obtained with the alternative mechanical injection system.

MAGNETISM

Performance of the Fahy Simplex Permeameter. Raymond L. Sanford. Bureau of Standards Journal of Research, May 1930, pages 703-709.

This report gives the results of a test of the Fahy Simplex permeameter which has come into quite general use for magnetic testing. The magnetic standards employed had previously been found to be sufficiently uniform to give results in the Burrows permeameter estimated to be accurate within less than 1 per cent. The experimental results indicate that the Simplex instrument is accurate within about 2 per cent with uniform bars, and that is gives more consistent and apparently more reliable results for nonuniform specimens than does the Burrows permeameter.

The Magnetostriction of Various Steels. J. S. Rankin. Journal Royal Technical College, Vol. 2, Jan. 1929, pages 12-19.

Paper describes a method of finding the change in length of various steels when subjected to magnetizing forces, the small changes involved being measured by oscillating thermionic valves.

The Effect of Tensile Overstrain on the Magnetostriction of Steel. J. S. Rankin. Journal Royal Technical College, Jan. 1930, pages 173-187.

An apparatus is described for detecting the change in the magnetostriction of steel after it has been subjected to different degrees of overstrain. It is shown that, whereas hard high-carbon steel shows less magnetostriction when soft low carbon steel, magnetostriction is greatly increased when soft low carbon steel is hardened by tensile overstrain. A theory, based on Webster's experiments on the magnetostriction of an iron crystal, on Joffe's analysis of plastic deformation, and on the results of the X-ray analysis of over-strained material, is suggested to account for the experimental results obtained. An appendix is added describing experiments on the magnetostriction of nickel, and of 25% and 30% nickel steel.

GENERAL

Report of the Twenty-Second National Conference on Weights and Measures. Miscellaneous Publication 101, U. S. Department of Commerce, 1929, 148 pages.

This report contains abstracts of the reports of the various state's weights and measures departments. It also contains the following papers read at the conference: The Federal Standard Container Act, H. A. Spilman; Standardization of Ice-Cream Cans, Brick Molds, and Cartons, R. Kennedy; Raising the Standard for Local Weights and Measures Officials, A. B. Smith; National Scale Men's Association Bulletin No. 1, on Repair of Heavy Capacity Scales, C. F. Hawkinson; Work of the Federal Trade Commission Relating to Weights and Measures, H. Anderson; Identification by Precision Methods of Comparison and Measurement, W. Souder; Weighing in the Meat Packing Industry, J. Holmes; Seasonal Aspects of County Weights and Measures Administration, G. L. Berry; Developments in Terminal Weighing of Grain, J. Schmitz; A New Testing Device for Large-Capacity Scales, C. P. Smith; Gasoline-Meter Installations in a Ramp Garage, B. Ragland; The Effect on Scale Design of Highway and Motor Truck Design, M. Starr; Methods for Investigating Reported Short Deliveries of Fuel Oil, E. Peffer; Observations on Certain Air-Operated Gasoline-Meter Installations, I. L. Miller; Reconditioning Rejected or Trade-In Scales, A. Sener; and Coin-Controlled Person-Weighing Scales, G. Roberts.

Temperature Regulators and Pressure Controlling Devices. E. H. Triphaus. Petroleum Engineer, April 1930, pages 192-198.

Paper presented before the Annual Plant Operators Meeting of the Natural Gasoline Men's Association of America, Breckenridge, Texas, April 22, 1930. The author discusses the application of temperature regulators and pressure controlling devices to the operation of the natural gasoline plant.

LENGTH, AREA, VOLUME

Methods of Measuring Tapered Bores. William S. Rowell. Machinery, April 1930, pages 589-590.

Describes in detail an apparatus and method for measuring slightly tapered bores which are relatively deep and not too small in diameter. It will not measure bores of excessive taper.—R.H.P.

Checking Positions of Angular Surfaces and Holes. William S. Rowell. Machinery, Mar. 1930, pages 549-550.

Gives two corrections for a method given in Machinery, Aug. 1929, page 924. These are necessary to allow for shrinkage of the ball in annealing and to provide a better fit of the balls in the bore. —R. H. P.

Electro-mechanical Gage for Fine Wires.(Electromechanisches Messgeraet fuer Feindraehte.) Max Bartholdy. Kruppsche Monatshefte, Nov. 1929, pages 184-185.

Errors are frequently introduced into measurements of the diameter of fine wires owing to the deformation of the circumference of these wires, to the non-parallelism of the measuring surfaces, to the dust adhering to the wire, and/or other detrimental factors encountered in the use of the usual measuring apparatus. The author briefly describes an apparatus enabling the accurate measuring of wires of 0 to 0.05 millimeter diameter which is designed to eliminate the above mentioned sources of error.—G. N.

Gage Blocks (Parallel-Endmasse) Zeitschrift fuer Feinmechanik und Praezision, April 18, 1930, pages 8-10.

The article is devoted to the manufacture of gage blocks and is taken from recent literature of Loewe—A. G. It has a general discussion of line and end measures, and the importance of the material and its treatment for gage blocks.

The New Zeiss—Profile Apparatus (Der neue Zeiss—Projektionsapparat) O. Daehne. Zeitschrift fuer Feinmechanik und Praezision, Jan. 15, 1930, pages 1-4.

The instrument is described.

Paper Thickness Micrometer with Adjustable Measuring Pressure. (Papierdickenmesser mit einstellbaren Messdruck) Zeitschrift fuer Feinmechanik und Praezision, Feb. 15, 1930, pages 4-5.

This instrument indicates on a dial with an accuracy of 0.001 mm.

A Simple Dividing Apparatus. (Ein einfacher Teilapparat) Rudolf Masek. Zeitschrift fuer Feinmechanik und Praezision, Oct. 15, 1929, pages 9-10.

The author describes a device originated by him, for use where there is not sufficient demand for a dividing machine.

Plug and Ring Gages. S. A. E. Production Engineering Standards, Society of Automotive Engineers, Jan. 1930, 9 pages.

Data and specifications on plug and ring gages.

LIQUIDS

Water Stage Recorder, An Accessory to the Current Meter. (Die Ergaenzung des hydrometrischen Fluegels durch schreibende Pegel) Zeitschrift fuer Feinmechanik und Praezision, Nov. 15, 1929, pages 6-7.

The Ott water stage recorder is described.

The Effect of Surface Waves on the Discharge Over Weirs. A. H. Gibson. Paper No. 4784, Institution of Civil Engineers.

Experiments have been carried out on weirs of four types, namely, a suppressed rectangular weir · a rectangular weir with two end contractions, a 90° vee notch, and a broad-crested weir. Heads ranged up to 6.5″ in the rectangular weirs, and up to 17″ in the vee notch, while the wave-heights ranged up to 8″. Wave-disturbance increases the discharge over a weir, the magnitude of the effect depending on various factors which are discussed. To a first degree of approximation the effect is the same as would be produced by a similar wave-system in which the internal velocities are zero, the pressure at any point is proportional to the depth of submersion, and the rate of rise and fall of the surface is so slow that at each instant the discharge is proportional to H 3/2, where H is the head on the weircrest at that instant. With waves whose height does not exceed the mean head on the weircrest and with a normal type of measuring weir, a correction may be applied, which will enable the effect on the discharge to be computed within 1%. The effect of waves on the discharge is less over a broad-crested weir than over a thin-crested weir, and is more irregular. In making use of the corrections given in the Paper, the wave-height should preferably be measured at a point distant about twelve times the mean head on the weir upstream from the crest, and, in the case of a weir having end contractions or of a vee notch, at a point approximately midway between the side and center of the approach-channel.

The Hydraulic Mean Depth as a Basis for Form Comparison in the Flow of Fluids in Pipes. J. Caldwell. Journal Royal Technical College, Jan. 1930, pages 203-220.

The experiments of Stanton and Pannell, Schiller, Davies and White and others on smooth brass pipes of circular, elliptical, rectangular and triangular sections show that when the friction coefficient is plotted against Reynolds' Function, in which the hydraulic mean depth has been taken as the characteristic dimension of the section, then one curve represents the relation between the coefficient and the Reynolds' Function for all sections. It has been suggested therefore that the hydraulic mean depth is a sufficient criterion for the geometric form of a pipe. The experiments herein described show that this is true only in special cases.

GASES, AIR, STEAM

An Apparatus and Method for Determining the Compressibility of a Gas and the Correction for "Supercompressibility." Howard S. Bean. Bureau of Standards, Journal of Research, May 1930, pages 645-661.

Boyle's law for gases states that the density is directly proportional to the absolute static pressures. All gases depart from this law to some extent, and this is especially true of the industrial fuel gases known as natural gas, for which the departure may be as much as 7 or 8% for a pressure range of 1 to 40 atmospheres. When these gases are metered at pressures of over 5 to 6 atmospheres this departure from Boyle's law becomes important, and a correction must be made to the meter indications by the introduction of a term called the "supercompressibility factor." In the experimental procedure for determining this factor a sample of gas is collected at high pressure in a steel cylinder of known capacity. Successive small portions of this sample are withdrawn into a burette where their volumes at atmospheric pressure are determined. This is continued until the whole sample has been reduced to atmospheric pressure. The sum of all these volumes at atmospheric pressure is then compared with the volume to which the initial sample of gas would have expanded if it had followed Boyle's law as the pressure was reduced to atmospheric. The derivation of the equation used in computing the factor from the observational data is given, and the steps to be taken in applying this equation are enumerated. Experience has indicated that the factors thus determined will be correct within 0.002. Based on the experience gained with the use of the apparatus described several factors of special interest are discussed. Other methods of determining the supercompressibility factor are also mentioned.

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A Gas Analysis Pipette for Difficult Absorptions. Martin Shepherd. Bureau of Standards, Journal of Research, June 1930, pages 747-752.

This note describes a bubbling pipette which employs a thin platinum distributor plate perforated with 200 holes of 0.06 mm. diameter. This distributor plate breaks the influent gas stream into many small bubbles, and effects intimate contact between a liquid reagent and the gas to be absorbed. The efficiency of the pipette has been compared with the ordinary bubbling type and with the Dennis-Friedrichs pipette. Oxygen is completely removed from air during three passages into alkaline pyrogallol contained in both the new pipette and the Dennis-Friedrichs pipette, whereas 10 passages were required for the ordinary type. The new pipette possesses some advantages over the Dennis-Friedrichs design, mainly lower cost, simplicity of construction, less fragility, and the fact that no special molds are required for its construction.

The Sentinel V-Notch Boiler-Feed Recorder. Iron and Coal Trades Review, Supplement, Jan. 3, 1930, pages I-II.

Describes the V-notch boiler feed recorder manufactured by the Lea Recorder Company, Ltd. of Manchester. It is a relatively small, light, portable apparatus which may be used by the small steam user.—R. H. P.

Effect of Turbulence in Wind Tunnel Measurements. H. L. Dryden, A. M. Kuethe. Report No. 342, National Advisory Committee for Aeronautics (1930).

This investigation was carried out at the Bureau of Standards at the request of and with the financial assistance of the National Advisory Committee for Aeronautics. The paper gives some quantitative measurements of wind-tunnel turbulence and its effect on the air resistance of spheres and airship models, measurements made possible by the hot wire anemometer and associated apparatus developed at the Bureau of Standards. The apparatus in its original form was described in Technical Report No. 320 and some modifications are presented in an appendix to the present paper. One important result of the present work is a curve by means of which measurements of the air resistance of spheres can be interpreted to give the turbulence quantitatively. Another is the definite proof that the discrepancies in the results on the N. P. L. standard airship models are due mainly to differences in the turbulence of the wind tunnels in which the tests were made. An attempt is made to interpret the observed results in terms of the boundary layer theory and for this purpose a brief account is given of the physical bases of this theory and of conceptions that have been obtained by analogy with the laws of flow in pipes.

The Flow of Air Through Circular Orifices with Rounded Approach. J. A. Polson, J. G. Lowther and B. J. Wilson. Bulletin 207, Engineering Experiment Station, University of Illinois.

Report of an investigation, the purpose of which was to study the flow of air through orifices by a precision method and to determine coefficients to be applied to Fliegner's formula for the flow of air

ELECTRICITY

Testing Insulation Without Destroying It. Robert Sparks. Electric Journal, April 1930, pages 229-230.

The power factor of insulation gives a measure of its quality. With the Schering bridge which is a modification of the Wheatstone bridge, a very accurate measurement of the loss angle of insulation materials is possible. The instrument is described and illustrated.—W. H. B.

Portable Instrument for Electric Meter Inspectors. (Hilfsmessgerat fur den Zahlerkontrolleur). Elektrotechnische Zeitschrift, Nov. 28, 1929, pages 1737-1738.

Describes small size portable measuring set which enables the meter inspector to ascertain whether the voltage windings of the meter have been interrupted by various causes such as overvoltages due to lightning etc., or whether the voltages in the three phase components of a measuring transformer are identical, without opening the meter at all and without its being necessary to disconnect it from the circuit.—A. J. M.

Compact, Flexible, Portable Relay Test Transformer. Fred P. Rhine. Electrical World Vol. 95 May 10, 1930, pages 935-936.

A description of a portable relay test transformer used by the Detroit Edison Co. It is characteristized by a wide range of available voltages, small dimensions and comparatively light weight of 34 lbs. The arrangement for testing timing relays is illustrated.—W. H. B.

Portable Apparatus for Measuring the Electrical Resistance of Rail Joints. (Schienenstossprüfer). Elektrotechnische Zeitschrift, Dec. 19, 1929, page 1857.

This apparatus represents a simple means for the convenient, frequent and accurate measuring of the electrical resistance of rail joints. It was devised with a view to enable a frequent inspection of these joints in regions in proximity of mines, for the purpose of avoiding the generation of parasitic currents which might prematurely set off miner's blasts.—A. J. M.

Novel Recording Device for Use with Measuring Instruments. (Un nouveau d'enregistrement pour appareils de mesures). P. J. Savary. Revue Générale de l'Electricité, Vol. XXV., Dec. 28, 1929, pages 1039-1042.

The device described is based upon the recording of deflections of the indicating needle of the measuring instrument by means of an electric arc generated between the indicating needle which is adapted to form one electrode and another electrode separated by the needle by a sheet of special paper. This paper is sensitive to the electric arc. Since the electric current producing the arc is of high frequency, the successive passages of the arc through the sensitized paper constitute a continuous graph or record of the deflections of the indicating needle. The author describes the apparatus in detail, explains the matter of its adaptation to various types of measuring instruments having a deflecting needle, as well as its advantages over other recording instruments.—M. S.

New Arrangement for the Measurement of Alternating Currents with Moving Coil and Permanent Magnet Apparatus (Nouveaux dispositifs de mesure de courants' alternatifs avec appareils à cadre mobile et aimant permanent). S. Held. Revue Générale de l'Electricite, Feb. 22, 1930, pages 277-284; March 1, 1930, pages 317-324.

Discusses first the advantages, from the point of view of precision, of moving coil and permanent magnet galvanometers for the measurement of continuous currents over instruments for measuring alternating currents. It is therefore of interest to rectify the current to permit the use of these galvanometers for alternating current. It is important, however, to find an easily used rectifier, of sufficiently precise operation that the readings of the measuring instrument shall not be adversely affected by its presence. The copper oxide-copper rectifier seems to satisfy these conditions. Describes the mechanism and characteristics of this rectifier, and then determines the relations between the mean values of the rectified current, the effective values of the alternating current and the galvanometer readings according to the various practical arrangements which may be considered.—M. S.

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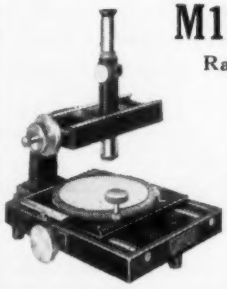

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Use of Radium in Measurement Spark-Gaps and Protective Apparatus for Overvoltages (L'emploi du radium dans les éclateurs de mesure et les appareits de protection contre les surtensions). R. van Cauvenberghe & G. Marchal. Revue générale de l'électricite, March 1, 1930, pages 331-337.

Investigation of the influence of the presence of radium in the interior of one of the electrodes of a spherical spark-gap on the regularity of its operation. Gives results of measurements made with the same spark-gap, first without ionization, then with an exposed arc-lamp, and finally with 0.5 and 10 mg of radium. A comparison of the results obtained with voltages at industrial frequencies proved interesting with regard to the use of radium in precise measurements with a spark-gap. At least as effective as the exposed arc lamp, radium in electrodes is particularly practical for measurements in free air.—M. S.

Progress in Remote Measurement (Fortschritte in der Fernmesstechnik). W. Brueckel & W. Staeblein. Elektrotechnik und Maschinenbau, March 2, 1930, pages 191-195.

Describes two new devices of the A. E. G. for remote measurement. The first is based on the compensating method and is suitable for continuous measurement with direct current on specific transmission lines. The second is based on the impulse time method and is applicable to all forms of transmission.—M. S.

Instrument Transformers. Electrical Review, Feb. 21, 1930, page 341.

Consists of extracts from three papers read before the Meter and Instrument Section of the Institution of Electrical Engineers. "A New Testing Method," by G. F. Shotter, describes a method based on the double-wattmeter method, with important modifications which are claimed to eliminate all its disadvantages "Precision Testing", by A. H. M. Arnold describes a method of testing current transformers speedily and accurately by means of a potential-divider bridge. The corrections to be made to the readings are deducted from the theory of the bridge." Accessory Apparatus", by R. S. J. Spilsbury and A. H. M. Arnold, describes some accessories for the precise measurement of alternating-current.—M. S.

An Extra-High-Voltage Laboratory. Electrical Review, March 7, 1930, pages 438-440.

Description of the million-volt equipment and high-frequency plant installed at the Trafford Park, Manchester, works of the Metropolitan-Vickers Electrical Co., Ltd., for investigation and research work.—M. S.

Watt-hour Meter Accuracy. A. E. Moore & W. T. Slater. Electrical Review, March 14, 1930, page 521.

From paper read before the Meter and Instrument Section of the Institution of Electrical Engineers. Discussion of the influence of frequency on errors at unity power factor. Results of investigation and deductions indicate that in order to reduce frequency errors, (1) the ratio of the active voltage flux to the permanent brake-magnet flux should be kept as low as is expedient, and (2) the time-constant of the eddy-current paths should be as low as possible, consistent with reasonably high torque.—M. S.

Electrical Measuring Instruments. (Elektrotechnische Messinstrumente) Alfred Nauck. Zeitschrift fuer Feinmechanik und Praezision, Dec. 18, 1929, page 4.

Ammeters, voltmeters, wattmeters and watt-hour meters very briefly discussed.

H. & B. Totalizing Instruments. (H. & B. Kreuzspulgeraete in Summenschaltung) J. Moeller. Zeitschrift fuer Feinmechanik und Praezision, Oct. 15, 1929, pages 5-8.

The instruments of Hartmann & Braun are described.

New Current Measuring Device with a Bimetallic Measuring System (Neue Starkstrommessgeraete mit Bimetallmesswerk) Johannes Becker. Messtechnik, April 1930, page 98-99.

The article briefly describes the construction of a bimetallic measuring system for current and voltage measurements.

The Wheatstone Bridge in Service Work. Part 2. James A. Dowie. Radio Service, May 1930, pages 6-7, 18.

Article covers measurement of inductance with the Wheatstone bridge.

Increasing the Range of Voltmeters. Radio Service, May 1930, pages 3-4, 20.

Article illustrates method of increasing range of a high resistance voltmeter by placing a resistance in series.

A Vacuum Tube Electrometer. R. H. Nelson, Review of Scientific Instruments, May 1930, pages 281-284.

The author shows how a specially constructed 3 element vacuum tube may be used in a simple circuit to measure accurately currents as small as 10^{-14} amperes.

A Constant Frequency Oscillator. Carl W. Miller & Howard L. Andrews. Review of Scientific Instruments, May 1930, pages 267-276.

The frequency of a vacuum tube oscillator depends not only upon the constants of the oscillating circuit but also upon those of the tube itself. In a tuned plate circuit, operating with minimum coupling the influence of the tube on frequency depends only on its plate resistance, and decreases as the plate resistance is increased. The steady drift in frequency usually observecd is due mainly to the effect on the plate resistance of progressive changes in the filament. Due to their rugged filaments the UX852 and the screen grid UX860 have been found particularly suitable for steady oscillators. Two methods of compensating for small changes in plate voltage and filament emission are described. A curve is included showing the effect of temperature on the frequency of the oscillator. The apparatus used for this precise study of small frequency changes is described. One of its most valuable features is an audio oscillator which is controlled by a vibrating string.

Note on a Modified Randall Universal Calibration Curve for Ballistic Galvanometers. Richard H. Frazer. Review of Scientific Instruments, May 1930, pages 277-280.

An experimental-graphical method is given for the determination of the critical damping resistance of a ballistic galvanometer. The curve used turns out to be a modification of the Randall Universal Calibration Curve which can be represented in the region of underdamping by a very readily drawn straight line with a maximum error of 1.8 %.

Increase of Capacity and Application of Measuring Instruments by the Use of Simple Expedients (Der Leistungsfaehigkeit und Anwendungsmoeglichkeit von Messgeraeten durch Verwendung einfacher Hilfsmittel) Bluhm. Elektrotechnische Zeitschrift, Mar. 6, 1930, pages 353-354.

A few electrical measuring instruments and their applications are discussed. The field of application of the instruments has been enlarged by the addition of simple optical devices. —H. A.

External Influences in the Measurement of Dielectric Losses of Fiber Bushings (Aeussere Einfluesse bei der Messung dielektrischer Verluste von Hartpapierdurchfuehrungen) P. Rosenloescher & E. Ruehlemann. Elektrotechnische Zeitschrift, Mar. 6, 1930. page 363.

Tests in the high tension laboratory of the Technische Hochschule Hannover showed that the best means for reducing dielectric losses due to concentrations of the electric field is a grounded protective metallic shield for the bushings without caps.—H. A.

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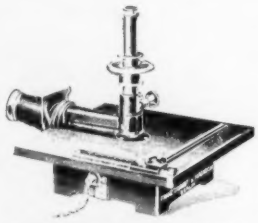

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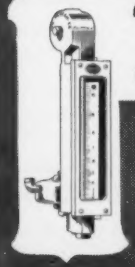

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ELMER A. SPERRY (1860-1930), INSTRUMENTS, Vol. 3, No. 7, July 1930, pages 410-411, 1 fig.

A brief biography.

WILLIAM HENRY BRISTOL . (1859-1930), INSTRUMENTS, Vol. 3, No. 7, July 1930, pages 411-413.

A brief biography.

MEASUREMENTS—INDUSTRIAL & SCIENTIFIC

DR. WALTER BLOCK, INSTRUMENTS, Vol. 3, No. 7, July 1930, pages 415-423, 2 figs.

Chapter VI, Measurements of Length: General Remarks and Standards, Verniers.

THE ENGINEER'S HANDBOOK OF INDUSTRIAL INSTRUMENTS.

M. F. BÉHAR, INSTRUMENTS, Vol. 3, No. 7, July 1930, pages 425-462, 40 figs.

Chapter II, Part 5—Temperature Control: Modes of Control, Requirements, Classes of Instruments and Auxiliary Devices.

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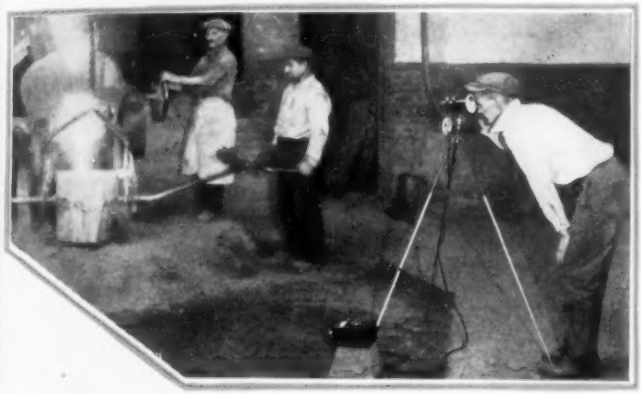

Showing the *Tycos* Féry Radiation Pyrometer on one of the many applications. Can be set up in one minute or used without tripod. Below, the instrument and indicator.

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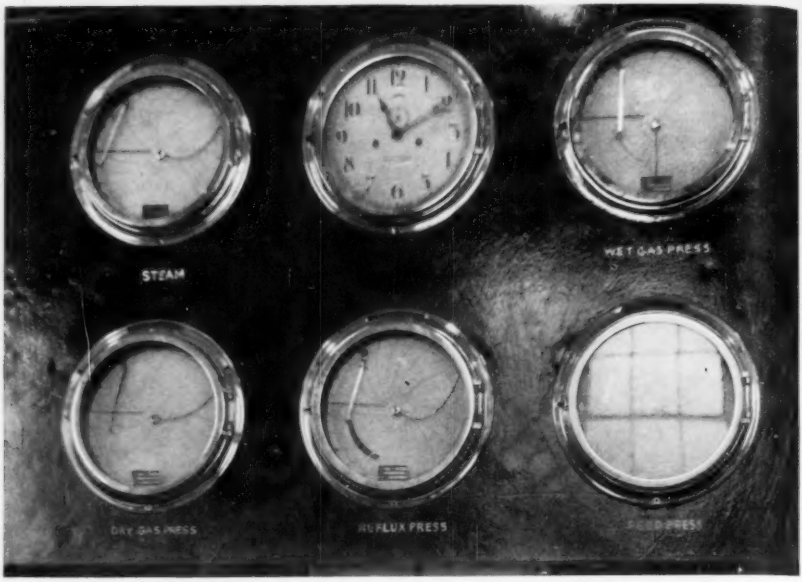
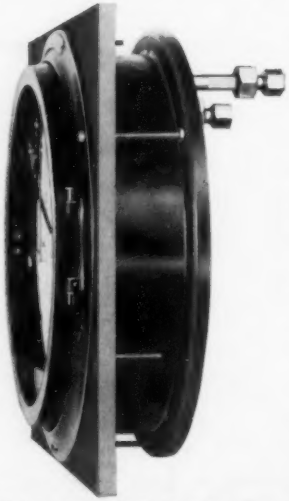


Above: Panel Board grouping showing portion of the twenty seven Bristol's Recorders in large Pennsylvania Oil Refining Plant.

Bristol's Recording Instruments

Arranged for Flush Mounting . . !



Side view of Bristol's 2-Pen Recording Gauge Model 43, which shows method of arranging instrument for flush mounting.

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